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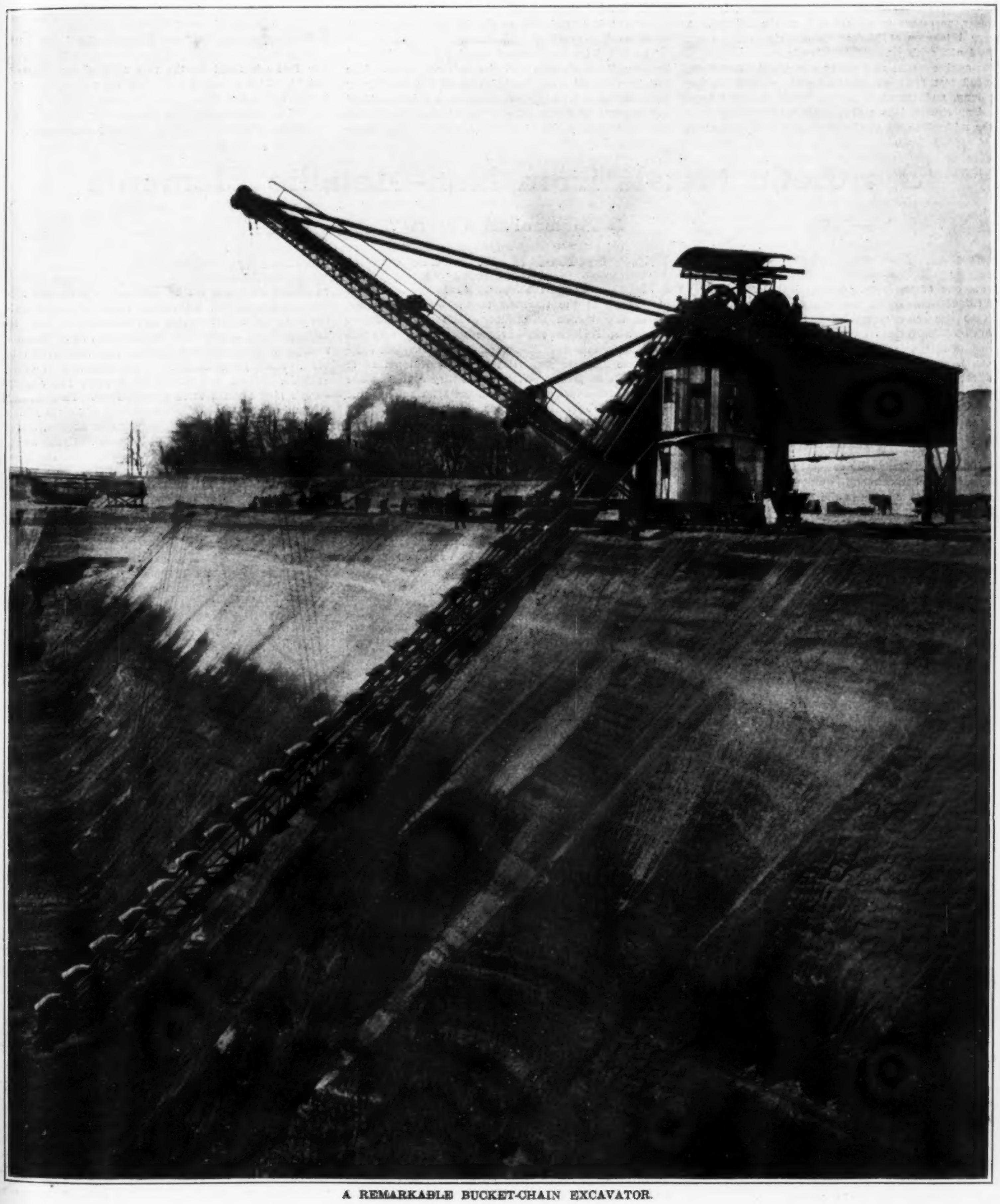


A REMARKABLE BUCKET-CHAIN EXCAVATOR.

A Remarkable Bucket Chain Excavator

Cement Digging by Machinery

The accompanying illustration shows an electric excavator in service at a Hungarian Cement Works as designed and constructed at Leipzig, Germany. This Bleichert excavation is of great capacity, as the guide alone has a length of 125 feet or 38 meters. The clay beds are composed of a comparatively light material, in layers of more or less sand, and moist, but not sticky clay, lying in 16 clearly defined horizontal layers, the upper ones being richer than the lower.

The material was formerly won and mixed by manual labor, but some years ago it was determined to substitute mechanical methods. To keep the works supplied with material of a uniform nature, it was, however, necessary to extract it from the beds, which have a thickness of 66 feet, in one single clean cut instead of working at different levels.

The engine works at a distance of about 400 meters, or 1,312 feet from the engine-house, on a track 930 feet long, and transfers the extracted material from two drop chutes, into a chain railway for conveyance to the mill. The cut of the excavator is in a straight line, as the bucket chain can only be shifted parallel to itself if the material extracted is to be kept uniformly mixed. The bucket chain is, therefore, guided entirely in the excavator guide.

The frame of the excavator is designed in rolled sections and well stiffened by cross and diagonal bracings. An electro-magnetic drive is used, the bucket chain being operated by an alternating current motor of 500 volts and 75 horse-power. The movements of the bucket chain, the traveling of the excavator and the raising and lowering of the bucket guide are quite independent of each other and can, therefore, be actuated either simultaneously or successively. The movement is transferred to the bucket chain by two drum sheaves provided with teeth.

The belt drive and toothed wheel drive are inserted between these sheaves and the driving motor. The belt is protected from the influence of the weather by plate casing, and, as is usual, the bucket guide is raised and lowered by means of a drum winch. The dredge buckets employed for digging out and carrying material are made in one piece from pressed-steel plates, and discharge to the rear.

There is a knife screwed on the blade side which can be easily sharpened or exchanged. The material handled is transferred from the excavator shovels to the loading pockets, from which it is drawn off into chain railway cars. The working angle of the excavator guide is 47.5 degrees. The track is horizontal with a gage of about 10 feet or 3 meters. The distance from the center of the traveling track of the excavator to the center of the chain railway is nearly 14 feet or about 5 meters. The projection of the counter-weight is about 50 feet or about 15 meters and the counterweight itself, which consists of paving stones, weighs 40 tons. The excavator has a length of 125 feet with a dredger depth of about 65 feet or 20 meters. Pendulum feet are fitted on the rear side of the counterweight, which comes to rest when the excavator guide is relieved at any time, so that at such times the main part of the counterweight is taken up by the feet. The excavator presents a rather striking appearance.

Synthetic Metals from Non-Metallic Elements*

Is Ammonium a Metal?

By Prof. H. N. McCoy

It is one of the most striking facts of chemistry that three-fourths of all the elements are metals. But it is no less remarkable that metallic properties are confined exclusively to elements in the free state or, in case of alloys, to combinations of typically metallic elements.

In recent years the theory of the nature of the metallic state has been steadily developing into more and more precise form, so that to-day we have, in the electron theory of matter, a very satisfactory explanation for all of the characteristic properties of metals. Inasmuch as it is just a century since Davy proposed his celebrated metallic ammonium theory, we may now well consider whether metallic properties are, of necessity, confined to elements in the free state.

During the last two decades a vast amount of experimental evidence has been accumulating that electricity is granular in structure, though such a conclusion was strongly indicated three quarters of a century ago by Faraday's discovery of the facts epitomized in the law of electro-chemical equivalents as first pointed out by Helmholtz in 1881. The granules or ultimate atoms of electricity are now called corpuscles or electrons. The charge of the electron is negative in sign. In fact we have decisive experimental evidence of only this one kind of free electricity, positive electrification of a body, being from this standpoint merely a deficiency of electrons.

J. J. Thomson has shown how from the conception of an atom made up of electrons rotating in a sphere of positive electrification, there follows a simple explanation of many of the properties of an atom, including valence a univalent atom, if negative, being one that can gain an electron, if positive, one that can lose an electron. A bivalent can gain or lose two electrons. A trivalent atom, three, etc. According to this hypothesis the most fundamental property of an atom of an element is this tendency to gain or lose one or more electrons. The tendency to lose electrons is greatest for the alkali metals and least for the noble metals. According to this view, for example, sodium and chlorine react with great energy because of the great tendency for each atom of free sodium to lose an electron, on the one hand, and each atom of free chlorine to take up an electron, on the other. The action consists, therefore, in the transfer of an electron from an atom of sodium to an atom of chlorine. The components of a molecule of solid salt are therefore not an *atom* each of sodium and chlorine, but an *ion* of sodium combined with an *ion* of chlorine, if by the term *ion* we now mean atom $\pm$ an electron.

The more or less complete, "electrolytic dissociation" or "ionization" which occurs upon dissolving a salt in water is then due to the marked lessening of the electric force which holds together the ions of the solid salt by reason of the very great dielectric constant of water.

The application of the electron theory to the metallic state by Riecke, Drude, Lorentz, Thomson and others has led to results of the highest significance. Though the details of the relations of the electrons to the atoms are viewed somewhat different by different physicists, it is however agreed by those who are working in this field that metals owe their most characteristic metallic properties of a physical nature to the *mobile* or free electrons which they contain. The absence of metallic properties in the solid non-metallic elements is, by this hypothesis, due to the supposed tendency of the atoms of such elements to *gain*, not lose, electrons: for which reason such a non-metallic solid will contain very few free or mobile electrons.

Thus, according to one view, electrons which are perhaps as numerous as the atoms of the metal, move about freely among the atoms, with which they are considered to be in kinetic equilibrium. Electric conductivity is then due to the drift of these electrons under the influence of the potential in the wire. Thermo-conductivity of metals is explained equally satisfactorily by the electron hypothesis. The calculated ratio of thermal to electrical conductivity and also the temperature coefficient of the ratio are in good agreement with the facts. Other metallic properties, including opacity to light, reflecting and radiating power, the Hall effect, the Thomson effect, the Peltier effect, etc., are equally well accounted for.

The most characteristic chemical property of a metal is its ability to form the positive ions of salts. Every true metal has this property well developed. If we electrolyze a solution of a salt, say silver nitrate, the free positive ions of silver are attracted and move toward the negative electrode; on coming in contact with which each ion has forced into it an electron, which converts it into an atom of silver. The aggregate of such atoms deposited on the cathode has metallic properties; owing to the great tendency of each atom to give up an electron.

When we come next to consider the behavior upon electrolysis of a salt of a compound basic radical, it is difficult to see wherein its behavior should differ from that of a salt of a metallic element. In this case, as in the other, positive ions are attracted to the cathode, and upon striking the latter can gain electrons. If then the electron theory of the metallic state is as fundamental as it seems to be, the aggregate of such free "neutralized" radicals should be a body having metallic properties; in other words, a "synthetic metal." For such a hypothetical body would be made up of radicals, which, analogous to metallic atoms, could easily lose electrons. The mass would then contain an abundance of mobile or free electrons and in such case possess high electrical and thermal conductivity, metallic luster, etc.

Turning now from theory to facts, the case of ammonium amalgam demands consideration at once on account of its historical importance. This remarkable substance was discovered practically simultaneously and independently by Seebeck, and by Berzelius in 1808; curiously enough, in just the same year that Davy isolated sodium and potassium from their hydroxides. Two years later Davy, in 1810, compared ammonium amalgam with the amalgams of sodium and potassium and was led to announce his famous ammonium hypothesis; the radical ammonium was analogous to the alkali metals and was said to exist in metallic form, united with the mercury, in ammonium amalgam. Berzelius and Ampere also supported this view. Some years later, after the discovery of other radicals, Dumas and Liebig in a joint paper gave Davy's idea a much more general form. They wrote: "Organic chemistry possesses its own elements which sometimes play the part of chlorine or oxygen, sometimes, however, also, that of a metal. Cyan, amid, benzoyl, the radicals of ammonia, the fats, the alcohols and their derivatives, form the true elements of organic nature." But the hypothesis of the metallic nature of ammonium in the amalgam did not pass unchallenged. Gay-Lussac and Thenard concluded that the so-called amalgam is only a mixture of ammonia, hydrogen and mercury; a view subsequently shared by many others, among them Seely, who found the volume of the inflated mass to be inversely proportional to the pressure upon it. The case against the metallic ammonium hypothesis was made still stronger by the evidence furnished by an experiment by Landolt in 1868. If the amalgam is really analogous to sodium amalgam, if the radical actually has the properties of a metal, it should readily precipitate from solutions of their salts metals of smaller solution tension; but, in the test, Landolt could precipitate neither copper nor silver with ammonium amalgam.

The first really convincing evidence in favor of the ammonium hypothesis was furnished by LeBlanc in 1890. LeBlanc electrolyzed a solution of an ammonium salt with a mercury cathode. The apparatus was so arranged that simultaneous measurements of the polarization potential could also be made. This potential rose in a few minutes to a maximum which was nearly as great as that given by a sodium salt. The really important result, however, was observed after the polarizing current was cut off. The mercury cathode, which showed the inflation characteristic of ammonium amalgam, was still strongly electro-negative toward the solution and remained so for from ten to twenty minutes. That this effect was not due to hydrogen was shown by the fact that the hydrogen polarization potential was considerably smaller and that it fell off almost as soon as the current was interrupted. These experiments of LeBlanc, based as they were on the sound principles of electro-chemistry, gave a new impetus to the ammonium hypothesis. Coehn, in 1900, reasoned that if ammonium amalgam gave the high potential found by LeBlanc, it surely ought to precipitate copper and silver, and that Landolt's experiments should succeed. But Coehn failed exactly as did Landolt! Coehn next found that at very low temperatures, or even at zero, the amalgam was much more stable than at room temperature, and would precipitate copper from coper sulphate without difficulty. This result was in itself insufficient to prove the metallic nature of ammonium, since free hydrogen was always present in the amalgam, and may have been the active substance in the reaction. To remove any doubt, Coehn then showed that not

*Read at the meeting of the American Chemical Society, Minneapolis, December 1910, and published in *Science*.

only are cadmium and zinc precipitated by the cold amalgam, but that barium amalgam results from the action at zero of ammonium amalgam on a solution of barium chloride. This fact was independently discovered later by G. M. Smith, who also obtained sodium and potassium amalgams in a similar manner. Thus the experiments of LeBlanc, Coehn and G. M. Smith furnish indisputable evidence of the metallic nature of ammonium in ammonium amalgam.

It is often stated that metals are insoluble in a physical sense, in all solvents excepting other metals. This statement can scarcely be upheld in view of the recent work of Kraus, on solutions of sodium, potassium, calcium, etc., in liquid ammonia. These very unique solutions, discovered by Weyl in 1864, seem to have many distinctive metallic properties. They are practically opaque, except when very dilute; even in this respect they resemble gold, which is transparent in very thin layers. They also show metallic luster, and reflection, and while they conduct the electric current, the conduction seems to be metallic rather than electrolytic in character. Upon evaporation, they deposit the pure metal in crystalline form. All such solutions, if sufficiently dilute, have a characteristic deep blue color. Now Palmaer has shown that by the electrolysis of tetraalkyl ammonium salts dissolved in liquid ammonia, unstable blue solutions are formed about the cathode. These blue solutions were thought to contain the organic radical in metallic form dissolved in ammonia. These facts have been confirmed by Kraus, who also concurs in the explanation.

LeBlanc's experiments on the polarization of mercury in solutions of ammonium salts, were also extended to include a similar study of salts of a number of substituted ammonias. Mono-, di-, and tetra-methyl and mono-ethyl ammonium ions gave results more or less like those of ammonium ions, from which facts LeBlanc concluded that in these cases also amalgams were formed, although none of the supposed amalgams were isolated. When attempts were made by Dr. Moore and myself to obtain an amalgam by the electrolysis of aqueous solutions of tetra-methyl ammonium salts the results were complete failures; not a trace of amalgam could be isolated. But when we substituted absolute ethyl alcohol for water, as solvent, the amalgam resulted at once. This amalgam differs greatly from ammonium amalgam in both appearance and stability. It is a crystalline solid of metallic luster, closely resembling sodium amalgam. It can be kept for days at temperatures below + 10 degrees and does not have any tendency to become inflated. Its density is somewhat less than that of mercury, but still many times greater than that of ammonium amalgam. Its electrical conductivity is comparable to that of a metal. Chemically, it resembles the alkali metal amalgams, but is far more active than that of sodium. It reacts with water with great energy and rapidity, giving hydrogen and the corresponding base, tetra-methyl ammonium hydroxide. From solutions of salts of copper and zinc, these metals are precipitated at once; while from solutions of salts of sodium and potassium the corresponding amalgams are formed. With solutions of ammonium salts the characteristic inflated mass of ammonium amalgam is produced.

The very high electrolytic solution tension indicated by these reactions is confirmed by direct potential measurements. The values obtained, for similar conditions, are about 0.6 volt higher than those found recently by Lewis and Kraus for sodium amalgam. This result is in harmony with the enormously greater activity toward water of the organic amalgam. Dr. Moore and I have also made mono-methyl ammonium amalgam and studied its properties.

The facts just discussed point clearly to the probability that in general positive ions, if free, or even amalgamated with mercury, will possess metallic properties. Practically, however, several causes may prevent the isolation of such metallic bodies. We know that it is not possible by electrolysis to separate many metals like sodium from aqueous solutions of their salts. Similar relations may obtain in the electrolysis of an organic salt. On the other hand, it is theoretically possible that such a compound metal may be so unstable in the free state that it suffers spontaneous decomposition at the moment of its formation from its ions. A third possibility is exemplified by the case of hydrogen. For a long time it was thought by some chemists that hydrogen in solid form would have metallic properties, since acids may be considered "hydrogen salts." The fact that solid hydrogen is now known to have no metallic properties proves clearly the fallacy of the old idea and seems to be also a flat contradiction of the hypothesis in question.

Now, hydrogen differs from the metals in one other important respect: while the molecules of metallic vapors are always monatomic those of hydrogen are diatomic. Thomson has considered the question of the theory of the union of two like atoms to form a molecule of an elementary gas, and has shown very convincingly that it is reasonable to conclude that one atom sends its valence electron into the other and that the combination is entirely analogous to that when two unlike atoms combine. If this is the case, it is possible to understand why solid hydrogen has no metallic properties its valence electrons are *bound* and not *free* nor *mobile*. Analogously to hydrogen, some organic radicals which can form positive ions of salts may unite in pairs to form double radicals. These would not be expected to have metallic properties.

In some cases, however, even hydrogen seems to have some metallic properties; it dissolves readily in palladium and, when nascent, diffuses easily through iron. The latter property of hydrogen may be due to continued existence in the monatomic and therefore metallic state.

As I have tried to point out, the electron theory of the metallic state would lead us to expect that free radicals, formed by the neutralization of the positive ions of salts by the introducton into each ion of that number of electrons represented by its valence would have metallic properties. The facts just reviewed, though few in number, seem to me to lend support to this hypothesis, and to lead to the conclusion that it is possible to prepare composite metallic substances, which may be termed synthetic metals, from constituent elements, some of which at least are non-metallic.

Hydro-Electric Plants in Norway*

Their Application to Electro-Chemical Industry

The physical configuration of Norway is remarkably favorable for the utilization of the large number of waterfalls to be found on the seaboard of the mountain chains which almost cover the country, and through the valleys of which the enormous quantity of water precipitated from the western and south-eastern sea breezes finds its way as rivers flowing down to the sea. In the winter the rainfall takes the form of snow, so that the volume of water brought down by the rivers is at its greatest from May to July, when the snows melt on the mountains. To make use of the water-power, storage is therefore necessary, and for this the nature of the country is peculiarly adapted, being covered with lakes that have very contracted outlets, and which can be easily converted by damming into storage reservoirs. Thus in the watershed of Skien the natural water-power of 50,000 horse-power has been increased to an available horse-power of 375,000, while the Mösvand reservoir has increased the water-power of the Rjukan factories from 30,000 to 250,000 horse-power, with a capital outlay of only some 85,000 pounds.

The total water-power in Norway has been estimated at from five to seven million horse-power, but as much of the country has not been hydrographically surveyed, this is probably too low an estimate. The power stations can supply power at from 22 to 44 shillings per electric horse-power year, and in some cases even for less; and as the quantities available are as high as from 50,000 to 100,000 horse-power for a single fall, the conditions are ideal for the development of electrochemical and electrometallurgical industries. Many such industries have already reached an advanced stage of development. Thus nearly 180,000 horse-power will be utilized this year in the manufacture of nitrates of lime, soda, and ammonia from the air by the Birkeland-Eyde process and the Badische Analin and Sodafabrik Company's process; about 60,000 horse-power are employed in the manufacture of calcium carbide, and other electrochemical and electrometallurgical industries absorb at present some 20,000 horse-power. Now that a suitable electric furnace—the Grönwall—has been designed for the smelting of iron ore, a furnace that has yielded excellent results on a practical scale, electric iron and steel smelting is likely to develop largely in the near future, for Norway possesses extensive deposits of iron ore. Three plants, aggregating 16,000 horse-power, with provision for increasing to nearly 60,000, are now being erected at Hardanger, Arendal, and Tinfoss. Other ores, notably copper, nickel, zinc, will also possibly be electrically smelted at no distant date.

The second portion of the paper describes in some detail the various hydro-electric schemes now being developed in Norway. On the Glommen River, in the east, three falls are utilized. The uppermost, Kykkelsrud, yields about 40,000 horse-power, of which 10,000 kilowatts is transmitted at 60,000 volts (3-phase 50 periods) to Christiania, thirty-one miles away, and the remainder to Sarpsborg. As Sarpsborg occurs the lowest fall of the Glommen, and here there are two power stations—Hafslund, supplying 24,000 horse-power to calcium carbide works and for zinc smelting, and Borregaard, the output of 26,000 horse-power of which is utilized by the Kellner Partington Paper Pulp Company, Ltd., owning the largest works in Norway. The intermediate fall on the Glommen is at Vamma, where a dam is now in course of construction under considerable difficulties. This dam will have a height of 90 feet, and will be one of the largest in Europe. The power station will be in the center of the river bed below the dam, and will yield some 70,000 to 80,000 horse-power.

A large number of the minor power stations in the south supply the towns with light and power. Among the smaller electrochemical works are the electro-iron and steel works at Arendal, the experimental nitrate works of the Badische Company at Christianssand, and nickel and aluminium factories near the same town. The nickel works refine nickel matte, and turn out about 400 tons of the pure metal per annum. At Gjössingfjord is Mr. Albert Hiorth's small experimental electro-steel works. At Vadheim, on the west coast, is a sodium factory, and at Trondhjem, in the north, carbide, ferro-chrome, and ferro-silicon are manufactured.

Another great power center is in the Telemarken district in the south-east of Norway. The Svaelgfoss power station supplies 40,000 horse-power to the nitrate factory at Notodden at a voltage of 10,000, delivered without transformation. The four 10,000-horse-power machines—capable of developing 13,000 horse-power—are among the largest in the world. A power station now being constructed at Lienfoss will be able to furnish Notodden with a further 20,000 horse-power. The Tinfoss Works, also at Notodden, are intended to generate 15,000 horse-power, to be used mainly for iron and steel smelting.

The third of the great Norwegian falls is the celebrated Rjukanfoss waterfall on the Maaneely River. The Mösvand dam, above this fall, provides a reservoir of about 840 million cubic meters (tons) of water, and five miles below is another dam, forming the intake for the power station, situated 1,000 feet below. A lower fall of about 1,000 feet provides the power for a second station. Both of these power stations—the largest in Europe—will yield 140,000 horse-power, there being in each 10 units of 14,000 horse-power. The turbines, on account of the great height of the falls, are Pelton wheels. The construction of the dams, flumes, and power stations at Rjukanfoss was attended with great engineering difficulties. The power from these stations is transmitted through sixty copper and aluminium cables to Saaheim, where factories for the manufacture of nitrogenous products to employ from 2,000 to 3,000 persons are in course of erection.

The power plant at the Tysse falls consists of seven units, each of 4,500 horse-power, from which electric energy is transmitted at 12,000 volts to Odda, where it is used for the manufacture of calcium carbide and of cyanamide. Here again, on account of the steep, mountainous character of the country, great difficulties presented themselves, particularly in the drilling of tunnels 1,320 feet above the fjord, and in fixing the flumes, some against a smooth precipice, with an inclination of 60 degrees. The Tysse power station will eventually yield some 100,000 horse-power.—*Nature.*

* Summary of a paper read before the Faraday Society on May 2nd by Mr. A. Scott-Hansen, of Christiania.

Fish Culture as an Anti-malarial Measure.—In the districts of Italy in which malaria is prevalent, the observation has been made that the fish living in the water devour the larvæ of the anopheles mosquito, which, as is well known, is the carrier of the malaria germs. On the basis of this observation, says *La Revue Scientifique*, experiments have been conducted in the valley of the Po, with a view to cultivating carps to fight the malaria mosquito. The experiments have led to very satisfactory results. The cost is very low, amounting to only about 40 cents per acre. As a matter of fact, this cost is made good by an increased yield of the submerged rice fields on which the carps have been introduced.

A Modern Gasoline Motor Testing Laboratory

Equipment for Work Under Varying Temperature Conditions

The accompanying illustrations, Figs. 1, 2, and 3, show the equipment of one of the most complete electric gasoline motor testing laboratories in the world as recently installed at Indianapolis, Ind.

The illustration, Fig. 1, shows the electric switchboard and dynamometer room and Fig. 2 shows the the refrigerating plant seen in Figs. 2 and 3 designed by Mr. Chase, testing engineer of the New York Auto Club testing laboratories.

It may be stated that the dynamometer is of the Diehl type with a capacity up to 120 horse-power. It it accurate at all speeds and under all load conditions, an air meter for showing the amount of air used, and this in connection with the gas consumption enables a gasoline and air chart to be prepared showing proportions used at all speeds. There is also a gas analysis apparatus for analyzing the properties of the exhaust gases and a pyrometer for measuring tempera-

Fig. 1.—Testing Laboratory Showing Electric Dynamometer and Switchboard.

Fig. 2.—The Compressor Installation and Exterior of Refrigerating Room.

compressor outfit, while in Fig. 3 may be seen the interior of the refrigerating room, located directly adjoining the dynamometer room. A road testing machine has been installed in this cold room. This machine is bolted to the dynamometer so that readings can be taken from the drive exerted by the rear wheels of the car in the refrigerating room, if desired.

It is stated that a temperature of zero can be reached in a short space of time and winter conditions can be obtained at any time and there is also provided a special fan and load absorber for motor cycle and small motors giving A. L. A. M. reading. It is claimed that this refrigerating plant is the only one of its kind in the world and will be of the greatest value in making actual tests under the most severe winter conditions, with different grades of fuel, and will demonstrate the results that can be obtained by various methods of applying heat to motors, manifolds and carburetters.

There is no question but that this is one of the finest testing laboratories in the world for testing gasoline motors of various types for motor boats, automobiles and motor cycles, as well as stationary engines. This laboratory consists of a dynamometer room as noted in Fig. 1, with test block for large motors and fan test for smaller ones, together with and has a special grid or load absorbing device, which obviates all corrections for errors such as have to be made with other methods of testing motors. In this laboratory of the Wheeler-Schebler plant there is also

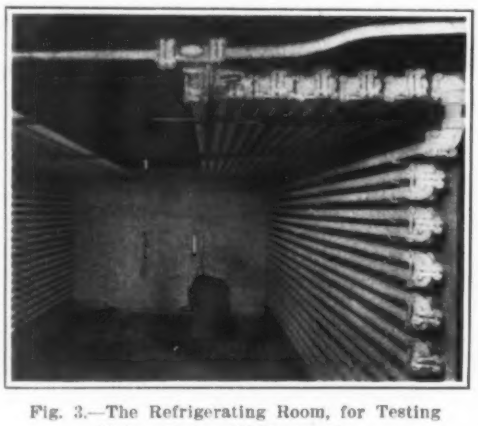


Fig. 3.—The Refrigerating Room, for Testing Motors Under All Temperature Conditions.

tures of the exhaust.

There are also provided a barometer which gives the atmospheric conditions and a manometer for determining the vacuum on the carburetter, and thus showing whether the proper size carburetter is being used on the motor under test. With these instruments a double check is obtained by measuring the volts and amperes as against the revolutions and pull, thus eliminating any possibility of errors in results. The water circulation is so arranged that any given temperature can be maintained under any conditions, and thermometers give the temperature of the intake and exhaust water circulation.

There are weighing scales provided for the fuel, and an electrical apparatus to measure the fuel consumption at all speeds, insuring absolute accuracy in this feature of the tests. The dynamometer is so designed that the motor exerts a direct pull by means of balance levers on a direct-reading spring balance, which determines the torque or pull. There is also provided a centrifugal and electrical tachometer for speed revolutions, one being a check against the other, and a Veeder counter or odometer attached to the shaft, giving the revolutions per minute. A watt meter is also included, giving instantaneous and accurate horse-power readings, at the various speeds.

The Direct Synthesis of Ammonia from Its Elements

The Catalytic Union of Hydrogen and Nitrogen

By F. Alex. McDermott, Washington, D. C.

A considerable amount of industrial chemical research has been devoted, within the past few years, to the fixation of atmospheric nitrogen in a form available for commercial use, more especially as fertilizers. The greater amount of this effort has been along the line of the production of oxides of nitrogen by the direct combustion of air, or air enriched with oxygen. There is, however, another form in which nitrogen may be made available for commercial use, i. e., that of ammonia.

Ammonia is a gas consisting of one atom of nitrogen united to three atoms of hydrogen, and contains about 83 per cent by weight of nitrogen. It is quite easily liquefied by cold and pressure. It unites with most acids, in the presence of water, to form what are known as ammonium salts, of which the chloride, sal ammoniac, is probably the best known example. These salts contain various proportions of nitrogen per unit of weight, according to the weight of the acid radical combined with the ammonia; thus the nitrate, NH_4NO_3, contains about 33 per cent of nitrogen, equally divided between nitrate and ammoniacal nitrogen; and the sulfate $(NH_4)_2SO_4$, contains about 20 per cent of nitrogen, all ammoniacal. Many of these salts are suitable for agricultural use, and indeed ammonium sulfate, from the ammoniacal liquors of the gas-works, has been in use for many years as a fertilizer and as the source of ammonia and nitrogen for all purposes.

A priori, from thermo-chemical data, it might seem that hydrogen and nitrogen should easily unite directly to form ammonia. The reaction between the two gases has been calculated to be exothermic, i. e., to generate heat, instead of absorbing it, and accordingly, if once started should produce enough heat to maintain the combination until the process were deliberately interrupted. But as a matter of fact, until quite recently, it has proven impossible to persuade these gases to enter into direct combination as ammonia and to stay combined. This is mainly due to the ease with which ammonia dissociates into its constituent gases at ordinary atmospheric pressure and at comparatively low temperatures (500 deg. C.), so that even when they had united, the very heat that had caused their union would break down the majority of the product again into nitrogen and hydrogen—or what amounts to the same thing, only a very small proportion of the two gases would actually unite.

Because of the obvious value of the product, a large number of the reactions known to produce ammonia have been studied, and attempts made to bring them to a degree of commercial usefulness.

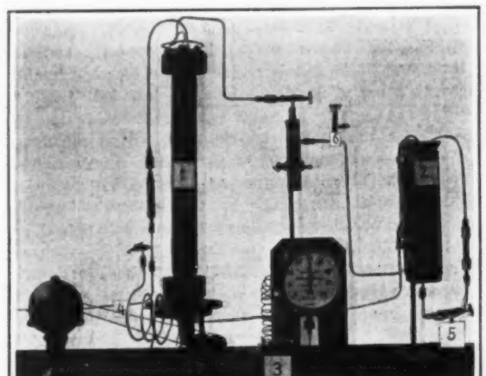
The first method which gave promise of value was that of passing an electric spark through a mixture of hydrogen and nitrogen in the proportions in which they are combined in ammonia. By this means the two gases may actually be combined in the form of ammonia, but if the ammonia be allowed to remain in the gaseous form, the same spark subsequently decomposes the compound gas, so that after a very little while a condition of equilibrium is reached where the amount of ammonia decomposed per unit of time is the same as the amount formed, and the process ceases to be productive. This may be overcome, of course, by absorbing the ammonia, as soon as formed, in an acid, with the formation of an ammonium salt, but though this is simple to state, practically it has failed to yield a satisfactory method for the production of ammonia. The application of electricity in this manner is not economical, and the necessity for

the use of some acid already formed increases the expense still further. It is not impossible, however, that this method may eventually be developed in some form which will prove commercially practicable.

It has long been known that when mixtures of oxygen, hydrogen and nitrogen or of air and steam, were passed over certain oxidizable substances—for instance iron, carbon, etc.—a certain amount of ammonia would be formed, the proportion depending upon a number of factors. An instance of this is seen in the occurrence of ammonia in small amounts in the raw gas from water-gas plants, where air and steam are blown through red-hot coals, a portion of the nitrogen of the air being converted into ammonia when the hydrogen produced by the reduction of the water by the hot coal is set free. Probably a much larger proportion of ammonia than is actually found is produced, and then decomposed again by the heat. This is the type of reaction that has recently been investigated by Woltereck, who has produced ammonia by blowing air and steam over coke, peat, etc., at temperatures of about 450 deg. C., and obtained yields of ammonia up to as much as 2.3 per cent of the weight of the carbon consumed. While this figure may appear small, it points the way to what may be accomplished by this type of process.

Still another type of reaction may be utilized for the synthesis of ammonia. Certain elements, such as boron, magnesium, titanium, etc., have the power of uniting directly with nitrogen when heated in contact with that gas, forming nitrides, which, when subsequently treated with water or steam, give up their nitrogen with the formation of ammonia and the oxide of the substance previously in combination with the nitrogen. Apparently the latest attempt to employ a reaction of this class was Lipski's work with cerium. He found that on passing hydrogen slowly over cerium nitride, or nitrogen over cerium hydride, at pressures of from 11 to 17 atmospheres, ammonia was produced, with the formation of the hydride of the metal in the first case, and the nitride in the second; he also found that both cerium nitride and cerium hydride acted as catalytic agents upon a mixture of nitrogen and hydrogen, producing small amounts of ammonia. Here there seems to be a practicable field opened up for the production of ammonia by definite and simple chemical reactions.

A fourth method which has been investigated as a possibility in the synthesis of ammonia from its elements is that depending upon the peculiar mechanism of catalysis. Numbers of reactions take place between various substances in the presence of another substance which appears to take no part in the reaction and does not appear in the end-products; typical examples of processes of this class are Deacon's chlorine process, and the "contact" sulfuric acid process. It was found that many substances had the property of catalyzing the union of nitrogen with hydrogen to form ammonia, among these substances being platinum, iron, ferro-manganese, broken porcelain, etc., but in all cases the amount of heat necessary to produce reaction decomposed a great part of the ammonia, and consequently the reactions were not productive. It has been stated herein that ammonia dissociates quite readily under atmospheric pressure, when the temperature is raised; by increasing the pressure, however, the point at which dissociation takes place may be considerably raised. Moreover, reactions frequently take place more readily under increased pressure. Working along these lines, F. Haber, of Karlsruhe, Germany, has recently brought out an apparatus and process for producing ammonia by catalysis. The catalytic agent in this process is finely divided metallic uranium or osmium, over which a mixture of hydrogen and nitrogen in the proper proportions is passed at a pressure of 175 to 200 atmospheres, and a temperature of about 500 deg. C. Under these conditions the gases combine in the presence of the catalyzer to form ammonia, which owing to the high pressure is not dissociated at the temperature employed, and may be cooled, liquefied, and drawn off from the receiving chamber in the liquid form. By this means as much as eight per cent of the mixed gases passing over the catalyzer are converted into ammonia. The accompanying illustration shows a working model of Haber's apparatus, with an explanation of the parts. The process has been patented, and taken up for commercial development by a German firm. Thus it seems that we have a practicable catalytic method for the production of ammonia from its elements, and therefore of the fixation of atmospheric nitrogen in the ammoniacal form.



Haber's Apparatus for the Catalytic Synthesis of Ammonia: 1. Reaction Chamber; 2. Liquefier; 3. High-pressure Circulating Pump; 4. Inlet-pipe for Fresh Gas Supply; 5. Cock for Drawing Off Ammonia; 6. Test Cock.

Of course in any process having in view the direct synthesis of ammonia the availability of relatively pure nitrogen and hydrogen gases must be considered. Nitrogen is obtainable fairly readily now, by the fractional evaporation of liquid air, and since the recent increase in aeronautic activity, commercial hydrogen is a more common product than formerly. Still, both are a little too expensive to be purchased already prepared and then utilized in this way. Hence it must be that a plant for the commercial production of synthetic ammonia would have to include its own apparatus for the production of nitrogen and hydrogen.

As yet, such a complete plant does not appear to have been constructed, but with the present activity in this field, we may soon have ammonia and its compounds produced from atmospheric nitrogen as ordinary commercial products.

A Tension-Tester for Aeroplane Wires

An Application of the Laws of Vibrating Strings

Modern industry has found means to produce steel wires of remarkable strength, which have been most welcome to the constructors of aeroplanes, where great strength and small weight must be combined. Unfortunately, such wires suffer under the very serious drawback that they are quite liable to break under bending stresses. There is reason to fear that a number of the accidents to aviators, which have been only too frequent, must be ascribed to such breaking of steel wires.

It would evidently be desirable so to adjust the wires as to impart to the aeroplane the required rigidity, while keeping the initial stress as small as possible, making use of only a small fraction of the breaking tension, and reserving practically the whole resistance of the wire to sustain the stresses incurred during flight.

This ideal condition is unfortunately far from being fulfilled in actual practice. Owing to the high coefficient elasticity of steel turning the adjusting screw of the wire even only two or three turns too far, may increase its tension per unit of cross section very considerably, and the mechanic who fits up the aeroplane has no criterion whatever by which to judge whether a given wire is unduly strained, or even whether the strain is evenly distributed over a number of wires. For this reason the wires only too frequently approach perilously near to breaking tension before the flight is started, and with the great speed of the machine and under the influence of the wind and gusts of air, sudden strains may be set up in the wires, causing that which is already under the highest tension to give way, and thus precipitating a disastrous accident.

One of the French corps of engineers, Capt. F. Largier, of the Fontainebleau Military Academy, has undertaken the task of designing an apparatus by the aid of which the tension of a wire could be readily ascertained at any moment. This apparatus is based on the well-known law governing the transverse vibration of a stretched string, according to which the product of the number of vibrations per second into the length of the string is proportional to the square root of the tension per unit of cross section. This formula would hardly be applicable in practice if a length of wire and the number of vibrations had to be measured in each case; Capt. Largier's apparatus, however, dispenses with both of these determinations, and allows the specific tension to be immediately ascertained by direct reading. The apparatus comprises two bars, inclosing between them a resonance box. On these bars are attached two bridges, one of which is fixed, while the other can be displaced along the bars, thus changing its distance from the other bridge.


The "Monochord" Tension Tester for Aeroplane Wires.

The wire to be examined is strongly pressed against the two bridges by two spiral springs, and the wire section comprised between the two bridges is lightly struck with a pencil or anything that happens to be at hand; the movable bridge is adjusted until the sound produced agrees with a standard (e. g., a tuning fork sounding a^3). The application of the formula which gives the tension of the spring in terms of its vibration frequency is thus greatly simplified, inasmuch as the frequency is made a constant throughout all determinations. In fact, the instrument can be so regulated as to allow the actual tension to be read off directly from a scale over which the movable bridge slides.

Diesel Engine Difficulties

A weak point in the Diesel engine, which is of great importance at the present moment, was brought out strongly in Mr. F. Schubeler's paper on the Diesel engine, read before the Institution of Mechanical Engineers at Zürich and is well worth emphasizing. The great possibilities of the Diesel engine have led to an enormous interest being taken in the subject, not only in the Press, but by manufacturers, some of whom had experience of building gas engines, some of whom have had none, so that the impression gained is that anyone who can make a steam engine can equally well draw out and build a Diesel engine. It is just here that a note of warning may be sounded. The "fit" and materials necessary to produce a good steam engine are now matters of common knowledge, but when it comes to the construction of a Diesel engine, experience, which alone gives the necessary knowledge is very limited, and the patent specification does not provide more than the smallest percentage of what is required to build an engine which will satisfactorily withstand pressures four times those which the steam engine builders have been accustomed to deal with. The successful builders of large-powered engines to-day are those who have been at work in this direction for years, starting with quite small units and finding and overcoming fresh difficulties with each progressive step. These difficulties must be expected to occur equally in the case of the first engine of any power—they will be exaggerated when that power is comparatively high. It cannot be too strongly urged upon manufacturers that the progress of the adoption of the oil engine afloat will only be "advanced backwards" by doubts being raised in the minds of the public owing to the want of immediate success of applications the inception of which has been heralded with the flare of trumpets, but based upon an entire want of appreciation of the great difficulties involved.—*The Engineer.*

Recent Developments in Astronomy*

A Review of the Present Status of the Science

By J. S. Plaskett

Let us begin our review of the progress of our science at our own globe, and though one would hardly state that the science of geophysics, as the study of the form and constitution of the earth is called, is astronomy, yet it cannot be disputed that only by knowing exactly the dimensions of our earth can we determine the dimensions and distances of the heavenly bodies; and only from a study of the constitution and physical condition of our globe, which must include careful measurements of the spectra of terrestrial elements, can we determine the constitution, the physical conditions, and the radial motions of the heavenly bodies. The science of geodesy, which treats of the figure and size of the earth, is making substantial progress all over the world, and new and more accurate data are constantly being obtained. It is a great satisfaction to me to record that, under the able superintendence of Dr. King, good progress is being made in an accurate Geodetic Survey of Canada. This work, which has only recently been organized, will furnish at the same time results of the greatest practical usefulness, as well as of the highest scientific value. The allied branches of seismology, terrestrial magnetism, and of the determination of gravity are, along with geodesy, gradually changing and crystallizing our notions of the structure of the interior of the earth from the old idea of a thin crust surrounding a molten interior to that of a solid globe whose density and elasticity increase with the depth, at least for some distance, which acts on the whole as if it possessed the rigidity of steel. Geodetic measurements show that all local irregularities on the surface such as mountains and valleys are completely compensated for at a depth of about 75 miles. This means that if, from the boundaries of equal areas on any part of the earth's surface, lines are drawn toward the center to a depth of 75 miles from sea level, the amount of matter inclosed is the same in each. This is called the isostatic layer and acts as if it were floating in equilibrium on a liquid at that depth. The comparatively new science of seismology on the other hand shows, from the form and velocity of propagation of earth disturbances, that the interior must be about as rigid as steel. This is further corroborated by measurements, by a kind of seismograph, of the deformation of the solid earth by the luni-solar attraction, which in the sea produces the tides but which also sets up, though, of course, very much reduced in magnitude, a similar effect upon the land.

The increase of data in terrestrial magnetism seems to have complicated rather than simplified the problem, which is, of course, naturally the case when the fundamental underlying cause or principle is unknown; and this it must be confessed is the case in this science. There can be no doubt, however, of its ultimate solution; and, indeed, we are beginning to see some glimmerings of light in the magnificent work being carried on at the Solar Observatory on Mt. Wilson, where one of the most recent and wonderful results has been to definitely prove that there are magnetic fields in the neighborhood of sun spots. That changes in the terrestrial magnetic elements and solar activity are in some manner connected has long been inferred from the frequent, nearly coincident appearance of violent magnetic storms following the central transit of prominent sun spots.

We pass naturally then from the earth to the sun, to us the most important heavenly body, as on it is dependent all life on our planet. Very great advances have been made in recent years in the study of the constitution of our luminary, and a great deal of attention is now being paid to researches in this most important branch of astronomy. The International Union for Co-operation in Solar Research, a society or rather group of societies which was organized about five years ago, and which embraces the workers on the sun in all civilized countries, has done much toward unifying and rendering effective the great amount of material collected. The work of the Union is carried on by several committees, which report at the triennial meetings.

One of the important conclusions reached by the Committee on Sun Spots was the practically unchanging character of sun spot spectra. To this may be added the fact, conclusively proved by Prof. Hale, that the umbra of sun spots is at a lower temperature than the rest of the sun's surface, and that in sun spots, as first found by Prof. Fowler, of London, we have the spectra of some chemical compounds such as titanium oxide, magnesium, and calcium hydride, further showing that the temperature is sufficiently reduced to allow the formation of such compounds, which do not appear in the normal solar spectrum. Again we have the discovery of Evershed, of Kodaikanal, India, of radial motions of the vapors around sun spots; and the final discovery by Hale, that many, if not all, sun spots are surrounded by whirls, and that electrically charged particles, which it has been further shown are negatively charged, are carried around by these whirls and produce the magnetic field which is shown to exist around sun spots.

At the high temperature of the sun, magnetism as we know it cannot exist, and the field must be produced by such whirls or vortices. The manner in which the magnetic field in sun spots was detected and proved is a splendid example of experimentation to test scientific deductions, and a full justification of the expenditure on the powerful apparatus needed for such work. The whirls surrounding sun spots are shown on photographs of part of the sun's surface, in the light given by the red line of hydrogen. Such photographs are made by the spectroheliograph, an instrument which enables us to photograph the sun's surface in the light of different gases or vapors, and hence records the distribution of these vapors. The great resemblance between these whirls and the lines of force around a magnet as shown by iron filings, led Prof. Hale, the inventor of the spectroheliograph and the discoverer of this effect, to suspect the presence of a magnetic field; and the next question was to verify this suspicion. It was found several years ago by Zeeman that if a luminous vapor is produced between the poles of a magnet, many of the lines of its spectrum are widened. Prof. Hale found that the spectrum of a sun spot, with the high dispersion available on Mt. Wilson, showed some of the same lines widened, strengthening his suspicion. Furthermore, when the widened lines produced by a magnetic field in the spectrum of a luminous vapor are examined through a polarizing apparatus many of the lines are split up into doublets, triplets, quadruplets or even sextuplets; and a similar test applied to a sun spot spectrum gave a similar though much weaker effect, conclusively proving the presence of a magnetic field. Comparison showed that its strength was about one quarter of that needed to saturate iron, too weak to produce any magnetic disturbance on the earth, and, therefore, incapable of explaining the frequent coincidence of magnetic storms and large sun spots.

Another interesting problem, which at the meeting of the Solar Union, was advanced a stage, is the determination of the Solar Rotation by the displacement of the spectral lines at opposite limbs of the sun. Owing to the rotation of the sun on its axis in about 26 days, one limb approaches and the other limb recedes from us, with a velocity, at the equator, of about 2 kilometers per second. If the spectra of the two limbs are brought side by side on the plate, the lines of the former will be displaced to the violet, of the latter to the red; and with a high dispersion spectrograph this displacement will be quite noticeable, of the order of one-tenth of a millimeter. Some work has been done on this problem by Duner at Upsala and by Halm at Edinburgh visually, and more recently by Adams at Mt. Wilson photographically. Besides determining the rate, and the law of decrease of rotation with different latitudes, there are other interesting problems, such as variations of the rate for lines of different substances, which require solution.

Although the study of the sun is most intimately connected with that of the stars, which was recognized at the Solar Union by the appointment of a committee to discuss the question of the classification of stellar spectra, yet we may, perhaps, turn for a moment to the other members of our solar system and see if any new light has recently been thrown upon the interesting question of conditions on other planets. The perennial question of the objective existence of the fine geometrical markings on Mars, commonly called canals, has been, during the last opposition of 1909, strenuously and ably supported by Lowell and one or two adherents, and equally strenuously and ably combated by many astronomers, chief among whom was Antoniadi. As is well known, the majority of astronomers are unable to see these fine sharp lines, although plenty of other detail is visible. During the last opposition, photography was used to a much larger extent, but I question whether it has settled the matter. Lowell says the principal canals show on his photographs, while others are unable to see them. The only way this question can be settled is, as Aitken suggested, for Lowell to invite some well known observers, such as Barnard, Burnham and others, to Flagstaff at the next opposition and let the whole question be fought out.

Another disputed point is the question of water vapor on Mars. The detection of this water vapor depends upon the visibility of a small band or group of lines in the red end of the spectrum produced by the presence of water vapor. Slipher, Lowell's assistant, photographed the spectrum of Mars and then the spectrum of the moon. The light from Mars, which is, of course, reflected sunlight, passes twice through Mars's atmosphere and then through the earth's atmosphere. The light from the moon, which has no atmosphere, passes through the earth's atmosphere only. If now there is water vapor in appreciable amount in the atmosphere of Mars this band should be stronger in the spectrum of Mars than in that of the moon. Slipher found that it was stronger in the Martian spectrum, but unfortunately some little time elapsed between the two exposures, and there is a possibility that the greater strength of the band was due to change in the amount of water vapor in the earth's atmosphere. Director Campbell, of the Lick Observatory, considered the question of sufficient importance to organize an expedition, carrying instruments to the summit of Mt. Whitney, elevation 14,500 feet, at which altitude only one-fifth of the earth's water vapor is above and four-fifths below. Any small difference between the moon and Mars bands will show relatively more conspicuously than at the elevation of Flagstaff, which is about 7,000 feet. His photographs were made within a few moments of one another, and with Mars and the moon at the same altitudes, and are hence directly comparable. I saw them myself last summer at Mt. Wilson, and I can say that there is no discernible difference in the vapor bands in the two spectra. The bands are very weak and evidently due to the small amount of water vapor present in the earth's atmosphere above Mt. Whitney. Campbell comes to the conclusion that there is no spectroscopic evidence of the existence of water vapor on the planet. Although he specifically states that he does not contend that Mars has no water vapor he says that it is too slight to be detected by the spectroscopic method and is probably considerably less in quantity than that present in the earth's atmosphere above the summit of Mt. Whitney.

The question of the suitability of Venus for organic life seems to depend upon the determination of its rotation period. If, as is now mostly believed, it always turns the same face to the sun then the one side will be baked and the other frozen. If, on the other hand, it turns on its axis in about 24 hours, then it is practically certain to be in a condition to support life. The only possible test between the two theories is the spectroscopic one, as in the solar rotation, by observing the line shift at opposite limbs. In this case, however, we have difficulties owing to the bad seeing at the comparatively low altitude of Venus and the disturbance of the image, so that it is difficult to determine in what region of the planet the spectra were made.

The advent of Halley's Comet proved possibly as disappointing to astronomers as to the general public for it did not show many unusual features and not much additional knowledge concerning the nature of comets was obtained. The motion of a detached part of the tail, as determined from three photographs at Williams Bay, Honolulu and Beirut, showed the presence of an accelerating force, as its velocity relative to the head increased from 23 miles to 37 miles a second in 7 or 8 hours. To my mind the most remarkable feature of its return was the accuracy of the computation so successfully carried through by Messrs. Cowell and Crommelin, in which they predicted its perihelion passage within less than three days. When considered in connection with the large number of disturbing elements to be taken into account and the exceedingly complex and cumbersome calculations required, their ephemeris was a marvelous piece of work, and they well deserved the recognition it received.

The subject of stellar photometry has always been a difficult one, as all the photometers hitherto devised have depended upon eye estimates or comparisons of the relative brightness of the star with either another star or an artificial light, made by ingenious devices to resemble and be brought close beside the star to be measured. There is, in all such methods, the possibility of psychological errors and it has not been possible to obtain, except in special cases, results with a lower probable error than about one-tenth of a magnitude. In the case of the comparison of two stars brought into the one field and equalized in intensity by polarizing apparatus, the probable error

* Address delivered before the Royal Astronomical Society of Canada and republished here in abridged form from the *Journal of the Society*.

is, perhaps, as low as three or four hundredths of a magnitude. In another method also, in which out-of-focus images of the stars are photographed, the density of the resulting disks have then to be measured by a photometer and we have errors of the same order. The new method, however, does not depend on eye estimates but on the change in electrical resistance of the element selenium when exposed to light. If a selenium cell is placed on the end of a telescope and an image of the star to be measured thrown on it, the change of resistance can be measured by a Wheatstone bridge arrangement and very accurate values of the brightness obtained. Prof. Stebbins, who has been working with much ability and energy on this problem for the last three years, deserves much credit for his success in a difficult research. He has recently made new measures of the light curve of the well known variable star Algol, and the probable error of a determination at maximum is $\pm$ .006 mag., at minimum $\pm$ .023 mag. The accuracy of his observations enabled him to detect a secondary minimum which had never before been seen and which indicates that the companion whose eclipse of the bright star causes the variability is not dark but light. Taking the most probable value of the parallax or distance of the star, he finds that the bright star, which has about the same diameter as the sun, gives 240 times as much light, while the faint hemisphere of the companion gives 16 and the bright hemisphere 28 times the light of the sun.

There has been a very marked advance in recent years in stellar spectroscopy, particularly in the line of the determination of the radial velocities of the brighter stars, and several observatories are now engaged in this work. Accurate radial velocity measures were first obtained by Prof. Campbell at the Lick Observatory in 1896 or 1897, and for many years he was practically the only one doing that work. Campbell's work has been the determination of the radial velocity of all stars in the sky, containing spectra with well measurable lines, which are brighter than the 5th visual magnitude. This work is now practically completed, and a preliminary value of the direction and magnitude of the sun's motion in space, with numerous other interesting and valuable deductions, are just being published.

In his work and that of Frost, of the Yerkes Observatory, who is measuring the radial velocities of Orion type stars, many spectroscopic binaries—stars whose radial motion varies, and which are hence accompanied by invisible companions, as distinguished from visual binaries where both stars are seen—have been discovered, and it is believed that not fewer than one in three of all stars must have a companion of approximately the same size, thus eliminating in these cases all possibility of a planetary system like our own. Great advances have been made in determining the orbits, the character of the motion around one another, of these binaries, and the two institutions most active in this line of work are the Allegheny and the Dominion Observatories. Of the seventy spectroscopic binary orbits determined our Observatory has obtained 16; which, considering that the aperture of its telescope is only half that of others or less engaged in the work and that it has been established only a comparatively short time, is a creditable showing. The great strides made in the determination of Spectroscopic Binary Orbits has led to no less than three summaries of the results, containing deductions of important conclusions from them: by Campbell, Schlesinger and Ludendorff. I have not time to enter into the results deduced from these discussions except to say that it was shown that most binary systems probably originate from a revolving parent nebula which, while condensing, separates into two masses, and that these masses, as condensation proceeds and by the influence of tidal action, gradually increase their distance from one another; this being accompanied, of course, by an increase in the period and also, as the results show, by an increase in the eccentricity—a greater departure from the circular form—of their orbits. There is no sharp line of distinction between spectroscopic and visual binary orbits except that the latter have much longer periods and generally higher eccentricities.

The information already obtained, and that which will in the near future be obtained about these spectroscopic binary systems, has a most important bearing on the problem of the constitution of the sidereal universe; and we must now come to consider recent progress in our knowledge of the extent and form and motions of its parts. This is certainly the most important problem in astronomy, as practically all observing data whether astrometrical or astrophysical, whether dealing with the absolute positions, proper motions, and radial velocities of the stars, with their distances, dimensions, and densities, with their evolution and spectral type, or with the investigation of variables and binary systems, are all either directly or indirectly obtained with this end in view and all are, undoubtedly, directly of use in its solution. As I said in the early part of the paper, there has been no time when so many different investigations were converging toward this end, and I will try and give you some details of the principal results.

One of the most striking of recent advances has been the discovery of star drifts and star streams in the sidereal universe. These have been discovered by statistical methods applied in the discussion of the absolute positions and proper motions of stars and also by the aid of their radial velocities. Although we speak of the "fixed" stars, the term is a misnomer, for they are all in motion. We can measure this motion in two components. First the motion at right angles to the line of sight, across the sky, determined from successive observations of the star's position in the sky and measured by the change of positions in seconds of arc in a year or a century. The change of position varies between 9 seconds per year and zero; the average annual proper motion, as it is called, for first magnitude stars being ¼ second and for sixth magnitude about 1/25 second, or 4 seconds per century. Second, the motion in the line of sight, or radial velocity, measured by the spectroscope, which again varies between 0 and about 250 kilometers per second, the velocity of a faint star in the southern hemisphere determined last year. It is evident that in order to get the true direction and velocity of a star we must know, in addition to its radial motion, its velocity in kilometers per second at right angles to the line of sight. If its proper motion is known this can be readily computed when we know its distance, and hence we can obtain the direction and magnitude of its motion.

In determining these motions we have to remember that we are on a moving body, the earth, which has a velocity of revolution around the sun of about 20 miles per second, and we must also remember that the sun, which is one of the stars, is also in motion. That this is the case has long been recognized, and the direction of this motion was determined from the proper motions of the stars by Sir William Herschel over 100 years ago. The method of doing this can be readily understood, for if we imagine the stars to be moving in all directions at random, it is, nevertheless, evident that in the portion of the sky which we are approaching, the general tendency will be for them to open out, while they will tend to close in in the opposite direction, and to drift backwards at the sides. Hence, if the motion of the stars is at random, it is only a question of mathematics to determine the direction and magnitude of the sun's motion in space.

Over twenty different determinations, based upon the proper motions of different numbers of stars, have been worked out, which all agree reasonably well in showing the sun to be moving towards the dividing line between Lyra and Hercules just a little south and east of the bright star Vega: (R. A. 270.5 degrees; declination + 34.3 degrees.)

If we consider, on the other hand, a determination of the apex of the Sun's Way, as this point is called, derived from the radial velocities of stars, we find it to be in a somewhat different position. In determining the velocity and direction of the sun's motion, the radial velocities of 1,073 stars brighter than the 5th magnitude, well distributed over the sky, were used, 1,020 of which were determined by spectrographs at Lick and Santiago, 40 were obtained from other observations and 13 were of nebulæ visually observed by Keeler. The position of the apex, or point toward which the sun is moving, is somewhere, about 7 degrees south of that obtained from the proper motions of the stars (R. A. 272.0 degrees $\pm$ 2.5 degrees; Dec. 27.5 degrees $\pm$ 3.0 degrees), nearly 10 degrees due south of Vega.

Of the two determinations the one obtained from a discussion of the proper motions is of the greater weight, for two reasons, first, the method is more suitable for determining direction; second, the number of stars employed is considerably greater.

On the other hand the discussion of radial velocities gives us a much more reliable value of the velocity of the solar system than proper motions. The velocity from Campbell's discussion comes out as 17.77 kilometers (11 miles per second), and this is undoubtedly very near the truth.

It is evident that if a comparison of the motions of the stars shows the sun to be moving toward Vega, then the apparent motions of the stars themselves must, on the whole, be to a point on the celestial sphere directly opposite. Such a motion of the stars, made up not of motions all in the one direction but of motions in all directions with a preponderance in one direction, is called a drift of the stars and there is thus a drift of the stars due to the solar motion toward or having as apex a point in the Southern Hemisphere nearly opposite Vega, with a velocity of about 11 miles per second.

About five years ago Kapteyn, from a careful examination and discussion of the proper motions of the Bradley stars, came to the conclusion that there is not one drift of stars, that due to the solar motion, but two drifts, moving in different directions. This conclusion has been confirmed by Eddington, Dyson, Hough and Halm, and the latest values of Eddington from the proper motions of Boss's Catalogue place the apexes of these two drifts as follows: Drift I. toward the constellation Lepus between Canis Major and Orion, about 10 degrees west of Sirius (R. A. 90.8 degrees; Dec. — 14.6 degrees). Drift II. toward the southern constellation Pavo or away from the northern constellation Camelopardalis (R. A. 287.8 degrees Dec. — 64.1 degrees). He finds that Drift I. is moving apparently nearly twice as fast as Drift II. and contains about 60 per cent of the stars.

When, however, allowance is made for the solar motion we find that these two drifts are moving, one toward the constellation Orion about 8 degrees northeast of α Orionis (Betelgeux), R. A. 94.2 degrees; Dec. + 11.9 degrees, and the other in the opposite direction exactly as if we were in the midst of two sidereal systems interpenetrating one another—a very fascinating hypothesis.

This hypothesis of the two drifts deduced from a discussion of the proper motions of the stars is strongly confirmed by Campbell's investigation of the radial velocities. We should expect, if there are two drifts of stars toward and from this point in Orion, that the radial velocities of stars in this and the opposite point of the sky should be greater than at points at right angles to these directions. Campbell found that the velocities in the vertex and anti-vertex are 33 per cent greater than at points about 90 degrees from these.

Besides the two drifts of stars we have smaller groups of stars in different regions of the sky, all the stars in a group having a motion approximately in the same direction and of the same velocity. Such groups are quite different from drifts where there is only a preponderance of motion in one direction, and are called star streams. Perhaps an analogy may help to make the matter of star drifts, star streams, and solar motion clearer. If you imagine yourself walking in a park where there are many people moving about at random it is evident that, speaking generally, the space between those you are approaching opens out, between those you are moving away from closes in, while people at either side, on the whole, appear to move backward. The apparent motion of the mass due to your own motion is analogous to the star drift due to the solar motion. If among the people there are, say, a company of soldiers or a picnic party moving in a given direction we have an analogue of a star stream.

It was first pointed out by R. A. Proctor, about 40 years ago, that five of the stars of the Dipper have proper motions in the same direction and of approximately the same magnitude; and this stream has within the last two years been thoroughly investigated by Ludendorff, of Potsdam, who determined their radial velocities, and more recently by Herzsprung, who found that the stars Sirius and α Coronæ Borealis as well as some fainter stars also belong to the group. It is a comparatively simple problem mathematically to determine the mean parallax or distance of such a stream when we know the convergent point or apex and the proper motions of the group with the radial velocities of two or three of them. The parallax of the five stars of the Dipper comes out as 0.0352 seconds, which is equivalent to a light journey of about 90 years, while they are all moving at a velocity of 20 kilometers per second towards a point in the southern part of the constellation Sagittarius ($\alpha = 303.2$ degrees, $\delta = -36.6$ degrees). It is shown further that the stars of this group are at the same order of distance apart as the sun is from some of the nearest stars—about 20 or 30 light years—and that they are about 100 times as bright as the sun.

The most recent discoveries in star streams were given by Prof. Kapteyn, at the Solar Union meeting, on Mt. Wilson, last August. He has found, by selecting from Boss's Catalogue all the stars of the Orion type, characterized by the appearance of helium lines in their spectrum and so called since most of the stars in the constellation of Orion are of this class, that in a large region of the sky they are moving in nearly the same direction and at nearly the same rate. This region contains the constellations Scorpio and Centaurus, covering 4,500 square degrees and extending roughly from 12 hours to 18 hours R. A. to and from Dec. 0 degrees to —60 degrees. In another region of 1,300 square degrees in Perseus from 2 hours 50 minutes to 4 hours 30 minutes R. A. and from + 15 degrees to + 55 degrees in Dec., all the stars of the same type are moving in a different direction. When motion of the sun among the stars is allowed for, Prof. Kapteyn finds that these apparent motions are equivalent to streams moving in exactly opposite directions and at equal rates. He finds these

stars are very distant from the sun, from about 125 to 500 light years.

It is evident that the sidereal universe is a complex structure and having complex drifts and motions of stars and systems of stars in its parts. We may be able to get a further idea of the magnitude of the problem by considering some of the recent results obtained for stellar distances. We all know, of course, that the nearest fixed star, α Centauri, is slightly over 4 light years distant, about 275,000 times the distance of the earth from the sun, 25 millions of millions of miles. There has been a very marked advance in recent years in the determination of the distances of the stars, so that we now know with reasonable accuracy by direct methods the parallax or distance of about 200 stars. If we take the blue stars, those of the 2nd magnitude are on the average 100, of the 4th 200, of the 6th 400, of the 8th 800, and of the 10th 1,600, and so on, light years away doubling for a change of 2 magnitudes: while if we consider stars of different types we have from a recent paper of Kapteyn's that the average distance of 5th magnitude stars is for the helium stars 500 light years, for the hydrogen 300, for the solar 130, for the late solar or fluted spectra 270 and for the carbon or deep red stars 4,500 light years.

Recent spectroscopic studies of some of the nebulæ have indicated, from the fact that their spectra are somewhat similar to our sun, that they are, probably, composed principally of solar type stars. If we consider the Great Nebula in Andromeda, which is a typical example, we are forced to the conclusion, if such is the case, that it must be tens of thousands of light years distant and probably forms a universe by itself. Indeed, it is practically certain that the globular clusters, like that in Hercules, which some of you have seen through the telescope, are compact aggregations of stars whose average distances from one another are of the same order as the distances of our sun from the nearer stars, say 5 to 20 light years and, in that case, the clusters are of the order of 10,000 light years distant from us.

The Uses of the Royal Palm

A Tree of Varied Utility

The royal palm (*Roystonea regia*, Cook) is one of the most striking vegetable features in Cuba and well deserves the name given to it, for it is surely the king of all tropical trees. It is the most conspicuous object which gives to the landscape a truly tropical appearance, and reminds the northern traveler that he is in a strange land. This tree is among the most graceful of palms, its marble colored stem, which rises frequently to a height of from 75 to 125 feet and attains a diameter of 2 feet, is perfectly straight and almost cylindrical, supporting a large crown of leaves 18 to 20 feet in diameter. It grows naturally on all the islands of the West Indies including the extreme southern part of Florida, Mexico, Central America, and northern part of South America. It occurs everywhere on the island of Cuba except among the pines, which are found chiefly on the higher and well-drained areas. The royal palm is abundant, especially in the moist, rich soil so well suited to the cultivation of tobacco (Fig. 1). The vast majority of royal palms now in existence especially in western Cuba stand on land which was cultivated at one time or another and later abandoned. In such locations the palms were able to secure a foothold before the competition of other plants became too strong.

Fig. 1.—Royal Palms Growing in a Tobacco Plantation.

Fig. 2.—Tobacco Wrapped Up in the Leaf Bases of the Royal Palm.

Although this palm is generally considered quite useless as timber, the thin outside layer of hard wood is employed extensively for making ramrods and walking sticks; it is used also for posts, fences, columns, boards, coffee mortars, gutters, and house walls. In fact the wood on the outside of the trunk is utilized in the country districts of Cuba for a great variety of purposes. The tree probably exceeds the cocoanut in total economic importance. The most useful part is the yagua or sheathing base of the leaf, which furnishes the simple Cuban many of his necessities. The large terminal pinnate leaves bear long sheathing leafstalks, which form a cylinder clear around the stem and are from 4 to 9 feet long with a width when flattened out equal to the circumference of the trunk. The leaves proper, of which there are about twenty, are attached to the upper end of the clasping bases, one of which is shed (Fig. 3) every three or four weeks, leaving a well marked ring where it was attached. These leaf bases are gathered immediately after they fall to the ground, dampened and flattened by means of weights. After they are thoroughly dried they are tied into bundles of convenient sizes and offered for sale. They form an article of sale in all places where the royal palms are scarce. There is a very good market for them in Havana and other centers of the tobacco industry. Formerly practically all tobacco that was sent to the United States and to Europe was carefully wrapped in these leaf bases, and it is said that there is no material better suited for this purpose. Even to-day all Cuban tobacco is bound up and shipped from the plantations in large bundles wrapped in these leafstalks. The palm is carefully preserved on all parts of the island and is largely cultivated for the sake of its leaves, which are consumed largely in the packing of tobacco for export (Fig. 2). Narrow strips torn off the edge of the pieces and twisted afford inexpensive yet very efficient tieing material. In the country districts of Cuba palm leaf bases furnish a most important portion of the string and ropes, and is used either in the twisted or untwisted state.

Fig. 3.—A Royal Palm with a Leaf Base Just About to Fall Off.

It also enters often into the construction of houses, and it is a curious sight in some of the sections where the royal palm is plentiful to see houses built almost entirely of this material. In fact a large proportion of the houses of the poorer classes are thatched or sided with yaguas, which are trimmed and tied to the framework of the house in a manner similar to that of shingles on the roofs of houses. Nails are never used to fasten them, but they are always tied to the rafters with palm leaf strings. Semi-cylindrical portions of the leafstalks are formed into cradles for negro children. They are also made into splints for fractures, and the inside skin when peeled off while green and dried, looks like vellum and bears ink on one side. The Cuban is using the leaf basis of this tree for almost countless other curious purposes, and the royal palm is therefore probably the most useful native tree, to say nothing of its value for ornamental purposes. While not bearing fruit or affording much shade from the tropical sun, every part of this tree is available for some use by the Cubans. Even the tender young leaves forming the terminal bud of the tree are utilized as a vegetable tasting like the most tender young cabbage.

The Number of Meteors Visible at Different Seasons.—According to *Cosmos*, Mr. Denning has examined the records of shooting star observations made in Bristol during the year 1866 to 1911. The frequency of meteors is maximum toward the end of July and the beginning of August. During the first six months of the year the total number of meteors observed on a clear moonless night is only about six per hour. At the beginning of July the frequency increases and attains its maximum, sixty-nine per hour, on August 10th. The mean for the entire year is twenty-four meteors per hour.

Frost Protection in Fruit Orchards

How Heavy Losses are Averted

The importance of the measures adopted to protect fruit in the Western orchards from frost can be realized only when we bear in mind the magnitude of the fruit growing industry, as compared, for example, with some of the other staple industries. In 1910 California produced 75,000,000 barrels of crude oil, nearly half the amount produced in the United States. It also produced more gold than any State or Territory in the Union. Compare with this the fruit crop, which in 1910 amounted to about $50,000,000. As Prof. A. G. McAdie points out, the gold and oil output may or may not increase during coming years, being governed at least in part by circumstances beyond our control; but the fruit crop is in a large measure dependent upon human activity, and there is every likelihood of a rapid increase in its value.

There are a number of causes which may tend to contribute to the losses incidental to fruit growing, but one of the most important of these is the occurrence of frosts at certain critical periods. Frost is treacherous in its action, and the work of a year may be made valueless in a single night. The proper course to pursue in warding off the danger must be determined by giving proper attention to a number of factors, and the solution of this problem requires a knowledge of certain physical facts and principles. Our knowledge of the exact temperature changes going on near the plant surface is as yet imperfect, and the processes by which frost crystals are formed upon the plants are not by any means fully understood as yet. There is a tendency for crystals to form at edges and points of leaves, blades, as everyone must have observed, and as appears in certain portions of one of the accompanying illustrations, showing a deposit of hoar frost upon blades of grass. The cover of frost or even ice which forms upon a plant, while it constitutes a signal of danger, is in itself rather beneficial. For as is well known, condensation of water vapor to water or ice is attended with a liberation of heat, which thus tends to mitigate the action of the cold. Again, in the subsequent period of thawing, the ice absorbs heat, and thus prevents too sudden a rise of temperature under the rays of the sun. It is often such sudden rise in temperature, rather than the previous freezing, which does damage to the fruit.

The Weather Bureau has been giving its attention to the problem of frost protection for a matter of fifteen years past, with results which are most satisfactory. Three lines of attack have been followed in grappling with the enemy. The first tactic has been the issuance of warnings of impending low temperature. This has not been by any means an easy matter, but it is most gratifying to report that during the winter of 1909-1910, in California there was not a single forecast of injurious frost that was not fully verified, nor did the warning ever fail to come from 12 to 36 hours in advance.

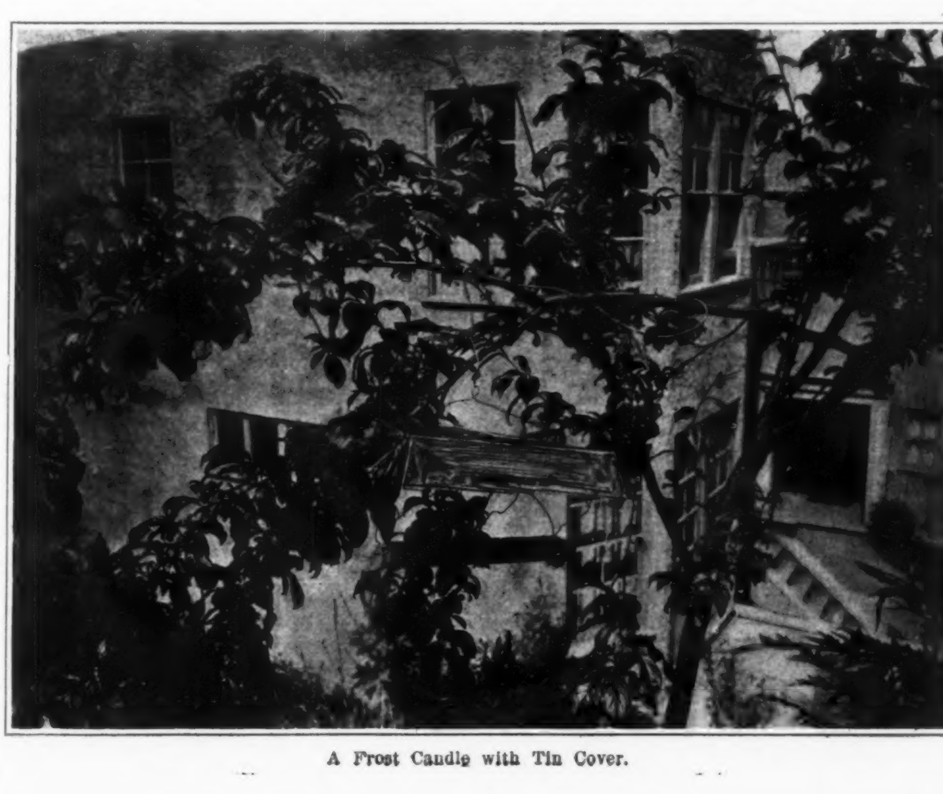
The second preventive measure which naturally suggests itself is to modify the plant stock by judicious selection and breeding in such manner as to create a race as far as possible resistant to low temperatures. Some work has been done in this direction, but in California the principal attention has been given to the third expedient, which comprises various methods of artificially controlling the temperature. The simplest way to attain this result is to burn fuel in the neighborhood of the plants. It is not by any means immaterial in just what way this is done. Large fires are neither economical nor efficient, heating up "all out of doors," as the saying is. Small fires applied more or less locally are more efficient, and there is quite a keen competition between various types of heaters now on the market. One simple device of this kind is shown in our illustration. It is a "frost candle" devised by the San Francisco Weather Bureau office. It consists of two portions, the lower or cartridge proper and an upper metallic screen or cover. The cartridge consists of a cardboard or stiff paper tube of suitable dimensions filled with combustible material. In actual practice, mailing tubes, about 12 inches long and 1½ inches in diameter, are used for the smaller size. For the larger size the dimensions may be doubled. The tube is filled with cotton waste or other suitable wicking and either crude oil or distillate. A stopper is provided for the lower end, but with a little experience the cotton waste may be so packed as to prevent any leakage of oil. A projecting end of the cotton waste serves as a ready means of lighting.

About 6 inches above the cartridge is a metallic cover, which is simply a sheet of thin metal, iron or tin, 20 inches long and 14 inches wide, cut along diagonal lines at each corner about 3½ inches. The ends are then bent downward making an inverted pan, the sides of which flare outward. The purpose of the inverted pan is to catch and hold a certain amount of the heated air rising from the burning end of the cartridge. It also serves to catch and hold the soot particles as they rise in the smoke. In burning crude oil the carbon is very noticeable and some means is necessary to prevent its settling on the fruit. The cover becoming heated will retain its heat longer than a screen of different shape, owing to its box-like character. Moreover the top surface, metallic, will radiate heat upward to the fruit a few inches above. This heat is preferable to the convectional heat from the naked flame, as it will not scorch or singe the boughs, leaves, or fruit.

The cartridge is held in place by a series of small loops made of wire, fastened to the edge of the cover.

A Characteristic Example of Frost on Grass.

Paper Cover as a Frost Protection.



A Frost Candle with Tin Cover.

Three of these holding loops are sufficient. The whole device, cartridge and cover, is hung under the tree, suspended from a bough by one or more wire hooks. The distance from the bough can be varied at will from a few inches to several feet. Preferably about 4 inches below the bough will answer.

The cartridges may be filled during the afternoon hours and set in their cradles. When the temperature falls to the danger point a man can pass through the orchard and with a small, flaming torch rapidly light the upper ends of the cartridges, which should burn gradually and completely, the entire cartridge being consumed. Tests made at San Francisco show that the cartridges will burn for about three hours.

One great advantage of the device is that the heat can be applied where most needed, namely, as close to the fruit as possible, and there is no heat wasted in warming up all out-of-doors. The method is cleaner than any ordinary uncovered system using crude oil, as the objectionable soot particles are in large measure deposited on the inner side of the cover. If the outer surface becomes black no harm is done, as, other things being equal, a black surface radiates heat better than other surfaces.

The covers remain in place until danger of frost is passed. They can then be stacked so as to occupy but little space.

A method of a somewhat different type which has been used to moderate temperature changes at nightfall and daybreak, consists in raising cloud of dense, steamy smoke in the orchard, for instance, by burning straw, old wood, prunings, refuse, etc., and sprinkling water over the fire. The cloud thus raised serves as a screen to prevent loss of heat by radiation, and as a barrier between the chilled fruit and a sudden application of heat at sunrise. This method does not seem to give uniformly good results, but some reports are quite favorable.

Still another expedient is to run pipe lines through the orchard and discharge steam into the air. In an instance on record the temperature was raised three degrees by turning on the steam. It is claimed that the coal consumed will not exceed that which would be used up in heating by the basket method. The expense per acre being about $1.75. Another somewhat similar method is to run warm water along furrows in the orchard.

After frost, or rather just before the frost has ended, a spraying device can be used to advantage. Its chief function is to prevent too rapid a warming of the chilled fruit. It is stated that oven a light coating of ice formed in this way does not seriously damage the fruit. The beneficial effect is probably due at least in part to the influence of the latent heat of the ice in delaying a rise of temperature, as has been indicated above.

Another type of protection against frost comprises a variety of covers, which work more or less on the hot-house principle. These may consist of lath screens or of paper covers, of which one is shown, for instance, in our illustration.

From this brief review of some of the principal methods employed it will be apparent to the reader that there is a great scope in the work of frost protection for good work along scientific lines. The values at stake are very considerable, and the results obtained in the past have been most encouraging. For the material which has been presented here, we are indebted chiefly to the monthly Weather Report and to bulletins issued by the United States Weather Bureau, the contributions being in large measure those of A. G. McAdie, who also kindly supplied the photographs.

Caisson Sickness and Compressed Air—II.*

The Cause of the Trouble and the Rationale of Its Treatment

By Leonard Hill, M.B., F.R.S.

Concluded from Supplement No. 1868, page 271

Direct Effects of High Pressures.—As all our experiments showed that dogs, cats and monkeys could be safely decompressed at a rate of 20 minutes per atmosphere from + 100 pounds, M. Greenwood and I went under pressure ourselves. A suitable chamber was supplied us by Messrs. Siebe, Gorman & Co. We used a steel boiler (volume 42.2 cubic feet) fitted with a telephone. In this one or other of us were exposed on eleven occasions to pressures above +60 pounds, four times to +75 pounds (M. Greenwood once went to +92 pounds). We were actually exposed to above +60 pounds for half an hour, and were virtually exposed for nearly an hour if we take into account the time of compression, which was slow. We were safely decompressed by the uniform method (about 20 minutes per atmosphere), only on two occasions suffering from minor local symptoms. From +92 pounds M. Greenwood was decompressed in 2 hours 17 minutes. Damant and Catto have since dived to the corresponding depth in the sea, and have been decompressed safely by the stage method. We found there is no sense of pressure, e. g., it is not possible to tell +3 from +5 atmospheres. The voices becomes very high pitched and nasal in quality, whispering and whistling impossible.

The respiration is normally regulated by the partial pressure on carbonic acid in the alveoli of the lungs, on which depends the concentration of acid in the blood passing through the respiratory center in the brain. Normally the partial pressure of CO_2 equals about 5 per cent of an atmosphere. We found this held good up to +75 pounds pressure.

Percentage of CO_2 Found on Analysis of Alveolar Air of Lung.	Pressure in Pounds.	Percentage Found Multiplied by Pressure in Atmospheres.
5.3	+ 0	5.3
0.9	+ 75	5.4
1.0	+ 60	5.0
1.8	+ 30	5.4
2.7	+ 15	5.4
5.4	+ 0	5.4

We collected and analyzed our alveolar air while in the caisson, and it was rather astonishing to observe the percentage of CO_2 fall as the pressure rose from 5.4 at 1 atmosphere to 0.9 at 6 atmospheres.

Methods of Decompression.—Saturation of the body with nitrogen depends on the relation between the circulating blood volume (the velocity with which the volume circulates) and the mass of the absorbing tissue fluid. The shorter time it takes for the blood to go round the body, the greater is the volume of the blood circulated per minute through the lungs and tissues. During saturation the blood carries the nitrogen from the lungs to the tissues; during desaturation it carries it from the tissues to the lungs. The rate of the circulation varies in different organs, and so the saturation time varies. There are parts quickly and parts slowly saturated. The fat absorbs five times as much as the watery tissue, and therefore takes much longer to saturate and desaturate.

The brain and spinal cord have much fat in the myelin of the nerve sheath. But as the brain has a more active circulation than the spinal cord, the white matter of the spinal cord is a commoner seat of bubbling, which leads to ischaemia, degeneration of the tissue, and paralysis.

*Journal of Royal Society of Arts.

According to Haldane, the whole body is about half saturated in half an hour, and about saturated in 4 hours. Bornstein thinks 6 to 7 hours are required for saturation of the fat. Bodily work, by increasing the circulation and pulmonary ventilation six times, or more, enormously reduces the time of saturation. Warm, moist caissons, by dilating the skin vessels and increasing perspiration, accelerate the circulation in the periphery, and make the saturation there far more rapid than in a man exposed to cool wind. The diver is surrounded by cold water, the caisson workman by warm, moist air. The latter generally works much harder and longer hours, and therefore suffers far more from "bends." The diver goes to much greater pressure for short times, and after quick decompression may suffer from asphyxia or paralysis—from bubbles in the heart or spinal cord.

Greenwood and I studied on ourselves the saturation of a quick part—the kidney. When the kidney is actively secreting, the saturation of the urine must approximate to that in the arterial blood.

One of us drank two pints of water, and half an hour later was raised to + 45 pounds. The urine filled a glass receiver, which was sealed, and the gases were extracted from it afterwards with the gas-pump. By this device samples of urine actually secreted in definite intervals, after a given pressure limit had been reached, were available for analysis. The results showed us that the kidney—in a state of activity—is about saturated in 10 minutes.

We were decompressed at a rate of 20 minutes per atmosphere, and our urine showed that desaturation lagged behind the fall in pressure. Our urine still contained an excess of gas at the end of decompression.

It is assumed that the blood is saturated, or desaturated, each time it passes through the lungs. The Admiralty tables of stage decompression are based on this assumption.

Figures which F. Twort, H. B. Walker, and I have obtained make it doubtful whether this is so. We breathed oxygen for 35 minutes and until there was only 10 per cent nitrogen left in the alveolar air of the lungs, and collected the urine *secreted then.* The amount of nitrogen dissolved under 1 atmosphere of air at body temperature is reckoned to be 0.825 per cent (Bohr). We actually found 0.878 per cent, using the Buckmaster and Gardner gas-pump, which gives the least possible source of error. After breathing the oxygen, we found 0.257 per cent, and on another occasion 0.316 per cent. We should expect to find, with a partial pressure of only 10 per cent atmosphere N, about 0.11 per cent. Either this extra nitrogen came from the kidneys, they having retained it, or else from the arterial blood.

The same lag is found in decompression experiments, and, considering the freedom of the diuresis, it is doubtful whether the kidneys can have retained all the excess of nitrogen, and it seems highly probable that the blood does not desaturate completely during its passage through the lungs. In dealing with this problem, the following came into consideration.

The two kidneys contain about 170 grammes of tissue water and perhaps 20 grammes of fat. As the fat has five times the saturation power for nitrogen, the solvent power of the kidneys would be equivalent to about 270 gramme of water. There is about 100 gramme of urine and a great volume of blood is circulating through the organs.

Time.	Pressure in Pounds.	Per Cent Nitrogen in Urine.	Per Cent Nitrogen Calculated.
4:00	+ 45	3.93*	3.47
4:06 – 4:12	Decompressed to 13	....	...
4:13	+ 13	3.70	1.62
4:22	+ 13	2.62	1.62
4:28	+ 13	2.30	1.62
4:34	+ 13	1.87	1.62
4:45	+ 13	1.80	1.62
4:45 – 4:52	Decompressed to 0	...	....
4:55	+ 0	1.64	0.825
5:00	+ 0	1.28	0.825

* The error of analysis makes the readings too high by 0.2 to 0.3.

On decompressing a resting animal, the nitrogen should be given up by diffusion from the lungs in the same time as that required for saturation. Now the viscosity of the blood prevents the formation of bubbles under a certain strain; hence it is safe for a man to be rapidly decompressed after exposure to about + 18 pounds (general experience of caissons).

It is safe, therefore, to come rapidly from 30 to 15 pounds (absolute), or half-way. Since the volume of a gas is halved at 2 atmospheres, made one-fourth at 4 atmospheres, one-eighth at 8 atmospheres, and the volume of a bubble is doubled on lowering the pressure from 8 to 4, 6 to 3, 4 to 2, or 2 to 1, Haldane concluded it was safe to come rapidly from 4 to 2, 6 to 3, or 8 to 4 atmospheres. The supersaturated tissues then give nitrogen to the blood, and the blood to the lungs, and the nitrogen escapes without bubbling at the half-pressure stage, where a long pause is given.

This stage method of decompression is of great value to divers, who only go down for a short period and do not work very hard, for it prevents the saturation of slow parts. The men are decompressed from the dangerous pressure to one half of it before the slow parts (fat, etc.) are saturated.

Caisson workers work hard and for long shifts, which means they are practically saturated. The Admiralty Committee, by experiments on goats, found a great superiority of the stage over the uniform method of 20 minutes per atmosphere, and established detailed tables of decompression on the strength of these experiments. These tables are drawn up, and give times of decompression with a great appearance of exactitude. They are based on theoretical assumptions as to the circulation time, volume of blood, desaturation of the blood in its passage through the lungs. As bodily activity has a most potent effect on the circulation, increasing the rate perhaps six or ten times, and converting "slow" parts into "quick" parts, it seems clear that the tables have only a lim-

lted accuracy. As I have pointed out above, the fact that the blood is desaturated in its passage through the lung requires proof.

Goats, moreover, are not the best animals for comparing with man, because of their chewing the cud, which leads to the swallowing of much air, and this, coupled with production of gas by fermentation, leads often to great distension of their viscera on decompression. We have lost several goats from this cause.

Greenwood and I chose, for investigation, pigs, which are more like men in shape, diet, and habit. We found no pronounced superiority of the stage over the uniform method. The pressure was + 75 pounds, the time of decompression 90 to 110 minutes, the same as that used in the Admiralty Committee's goat experiments. There were 4 fatal or dangerous cases in 20 uniform, 9 in 32 stages, and 9 in 44 modified uniform, decompression rate slowing in proportion as pressure falls.

Using a longer period, we have found it fairly safe to decompress pigs or goats by a one-stage method from + 75 pounds. The method was + 75 to + 18 pounds in 10 minutes, and +18 to +0 pounds in 20 minutes, after an interval of 80 to 100 minutes. One death and no severe cases resulted in 47 pigs weighing 50 to 100 pounds, 1 severe and 3 slight cases in 19 goats weighing 39 to 57 pounds.

Similar decompression of fat pigs from + 90 pounds, allowing an interval of 105 to 120 minutes at + 18 pounds, gave unfavorable results—7 deaths and 1 severe case in 27 pigs. These pigs weighed 81 to 115 pounds, and the fact that they were very fat and never moved during decompression told greatly against them.

Only one pig out of all showed any symptoms after being decompressed in 10 minutes to the stage at + 18 to 20 pounds. It is therefore safe to use the stage method for a man; the only question to settle is the duration of the stage and the handling of the second part of the decompression.

Bornstein has compared the stage and the uniform method at the Elbe Tunnel Works (+ 2 atmospheres).

Days.		Workers.	Cases of Illness.	Illness per Day.
20	Stage.	526	15	0.94 (?) 0.75
16	Uniform.......	528	17	1.21 (?) 1.06
18	Stage	529	12	0.67
16	Uniform	529	14	0.88
14	Stage.	536	12	0.86

The figures show a slight advantage for the stage method, but it is within the limits of error, for the number of cases from time to time vary widely in caisson works. Bornstein has got much better results by making the men climb a ladder 25 meters high immediately after decompression, so as to excite the circulation and pulmonary ventilation.

No Climbing After Decompression.

Days.	Workers.	Cases of Illness.	Illness per Day, Calculated on Basis of 1,000 Workers.
31	527	56	3.37
33	529	43	2.13
13	536	17	2.26

Climbing After Decompression.

Days.	Workers.	Cases of Illness.	Illness per Day Calculated on Basis of 1,000 Workers.
24	407	4	0.39
27	338	17	1.80
13	328	4	0.87
13	162	4	1.79
12	112	1	0.59

In this respect I note that Mr. Francis Fox states that when he visited the St. Louis Works (57½ pounds) he found the morbidity greatly lessened by the substitution of lifts for climbing after decompression.

I do not think violent exercise would be wise *after* too short a decompression from a high pressure. Making our pigs struggle has several times brought on symptoms. The exercise should be given during the stage interval.

Eight thousand five hundred man-shifts were decompressed by Japp at the East River Tunnel, New York, by a stage method—from + 40 pounds in 48 minutes. There were 1.62 per cent cases and no serious ones. The method used was, (1) + 40 to + 29 pounds in 5 minutes; (2) 10 minutes' walking in + 29 pounds; (3) + 29 to + 12½ pounds in 8 minutes; (4) 10 minutes' walking in + 12½ pounds; (5) + 12½ to 0 in 15 minutes. Lengths of tunnel were arranged between locks for walking in. The Admiralty table ordains 92 minutes for this pressure. Half this time, evidently, is enough, and no doubt less if the men were made to do hard muscular exercise during the stages.

Bornstein calculates the same volume of nitrogen expelled by uniform decompression in 1 minute would be expelled by stage decompression in 0.5 to 0.6 minutes.

	Minutes.
Breathing oxygen..........................	.... to 0.35
Forced breathing...........................	0.5 to 0.9
Light bodily work..........................	0.2 to 0.25
Heavy bodily work.........................	0.1 to 0.2

Greenwood and I, in the experiments on ourselves, realized the importance of muscular work, and by exercising ourselves were decompressed safely from pressures which have proved dangerous for fat, somnolent pigs. We in vain tried to make the pigs exercise by giving them electric shocks. I have no doubt that the best method to shorten decompression safely is to make the men work during decompression. They should be made to climb at the half-pressure stage.

Breathing Oxygen to Hasten Decompression.—F. Twort, H. B. Walker, and I have investigated this by the urine method. We have breathed oxygen during uniform and stage decompression, and observed its effect by analysis of the nitrogen gas in the samples of urine collected every 7 minutes.

Oxygen helps to clear the nitrogen out, as this experiment shows:

Time.	Pressure in Pounds.	Per Cent Nitrogen in Urine.	Per Cent. Nitrogen, Calculated.
12:50	45	3.83	3.47
12:53 12:57	Decompression to 30.	....	....
12:57 1:01	Decompression to 15. Breathed oxygen for two minutes	....	....
1:02	15	3.22	1.70
1:04 1:07	Breathed oxygen.	....	....
1:09	15	2.13	1.70
1:10 1:15	Decompression to 10. Breathed oxygen for 3 minutes. Oxygen supply then gave out.	....	....
1:16	10		
1:23	10	1.68	1.42
1:30	10	1.45	....
		1.76	....
1:32 1:33	Decompression to 5.	....	....
1:37	5		
1:40		1.61	1.12
1:44	Decompression to 0.	1.35	0.825

Bornstein has breathed oxygen (90 to 95 per cent) for 48 minutes (at + 2 atmospheres), and two engineers at the Elbe Tunnel breathed it for 30 minutes. These important observations show the limit to which such high partial pressures of oxygen can be breathed safely by man. Bornstein has found the time limit given above must not be overstepped. He freed himself from "bends," after 8 hour exposures to + 2 atmospheres, by using oxygen.

The oxygen can be breathed economically by the use of the Fleuss apparatus,* which was used so effectively in the last great colliery disaster at Bolton. This apparatus can be put on in the works and oxygen breathed for 10 minutes before and again during decompression. This, coupled with active exercise to excite the circulation, ought to clear out most of the nitrogen in a very few minutes. For every atmosphere the body dissolves nitrogen to about 1 per cent of its mass—for a 70 kilogramme man, say, 700 cubic centimeters atmosphere. Von Schrötter calculates that oxygen plus muscular exercise would turn out 1,000 cubic centimeters in 5 minutes, probably more. We are at present investigating this interesting point.

Length of Shift.—It is generally held that length of shift increases risk (E. W. Moir, Bornstein). Bornstein says he can be decompressed from + 2 atmospheres in 20 seconds after 50 minutes exposure, while he suffers from "bends" after 8 hours exposure if decompressed in 20 minutes per atmosphere. Bends, no doubt, are due to saturation of the peripheral "slow" parts. Bornstein says a much slower rate is needed for 8 hours than for 1 to 2 hours or 2 to 4 hours shift. To prevent bends, no doubt this is the case, but I doubt whether there is evidence that dangerous cases are much more frequent with 6 to 8 than with 3 to 4-hour shifts. The question of saturation is complicated by that of fatigue: a long shift fatigues the circulatory mechanism and makes it inefficient during decompression.

Neither the tables of the goat experiments of Boycott, Damant, and Haldane, nor the tables of Keays concerning the 557,000 man-shifts at the East River Tunnels, give conclusive evidence that shifts of 3 hours are more dangerous than 1½, or 8 than 3.

The variations in percentage of cases, even when calculated from groups of 3,000 to 4,000 man-shifts, are very large, e. g., 8-hours shift 0.43 per cent, May, 1907, and 0.94 per cent January, 1907. Chance plays a very big *rôle*. The first 3-hours shift gave 0.35 per cent cases, and 9 fatal or dangerous in about 43,600 man-shifts; the second 3-hours shift (after 3 hours interval) gave 0.72 per cent cases, and 4 dangerous or fatal, in the same number of man-shifts. The sum of cases for the six hours is 1.07 per cent. The percentage in 10,700 man-shifts of 8 hours is 0.62. Two 3-hour shifts with a 3-hours interval appears, then, to be almost doubly as risky as one 8-hours shift, because it doubles decompressions. The percentage of illness was 0.66, of death 0.0035, in 557,000 man-shifts, with a decompression rate of 15 minutes from + 29 to + 33 pounds.

As bubbles persist for a long time, and may act as starting-points for the formation of other bubbles, it is wise to give long intervals of time between successive shifts in deep-water work. Bubbles have been seen in veins of animals killed 48 hours after decompression (Bert, Haldane). They last for days in the spinal cord (Boycott and Damant), and in the subcutaneous fat of pigs.

Recompression of the Greatest Value.—Of the above 3,692 cases among 10,000 men, 89 per cent were bends, 5 per cent vertigo = 95 per cent non-dangerous; 1.26 per cent pain and prostration, 2.16 per cent paralysis, 1.62 per cent dyspnœa, 0.46 per cent collapse = about 5 per cent dangerous.

Recompression in the medical lock relieved 90 per cent, and of the rest all but 0.5 per cent were partly relieved. Oxygen breathing could be used with great effect in the medical lock, and it ought to be always at hand there. Down Brothers make for me a small face-mask, by which the gas can be administered efficiently from a cylinder of compressed oxygen. The ordinary way of giving it to patients through an open funnel or nozzle is most inefficient.

Von Schrötter has suggested breathing hydrogen or marsh gas to dilute the oxygen and wash out the nitrogen—a dangerous mixture to use, and I cannot see how it will help, for these inert gases will be dissolved and take the place of the nitrogen.

Fat in the Food.—The following observations made by F. Twort and myself show how water behaves when reduced from + 90 to + 20 pounds, and either left quiet or gently shaken.

Water Shaken for Thirty Minutes at + 90 Pounds.

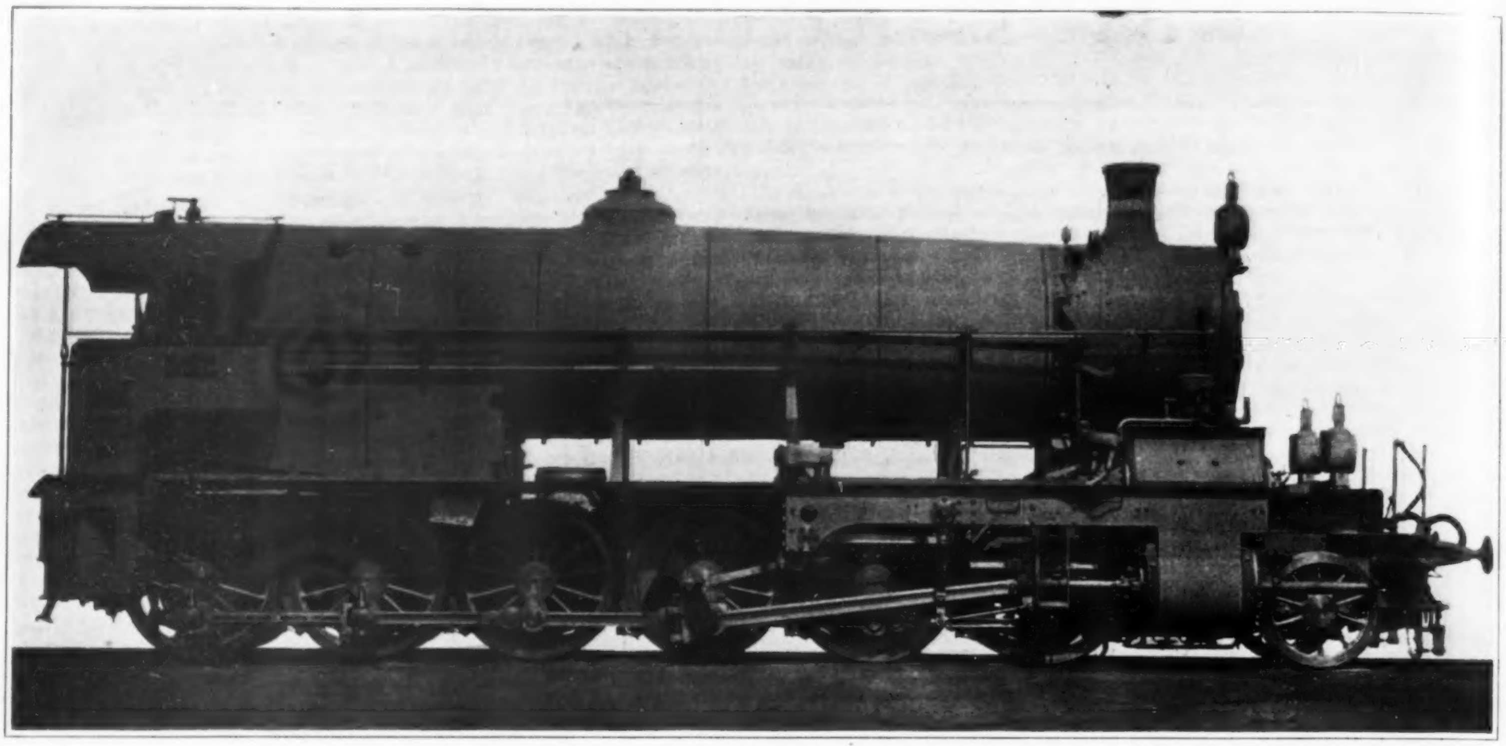
Dissolved Air Found.	Dissolved Air at + 90 lbs. Calculated.	Dissolved Air at + 20 lbs. Calculated.	When Collected.
15.1	15.71	....	At + 90 lbs.
14.9	15.28	....	At + 90 lbs.
14.42	15.88	5.26	At + 20 lbs.
9.26	15.28	5.06	After 2 hours at + 20 lbs.
9.78	15.74	5.16	After 2 hours at + 20 lbs.
8.26	16.35	5.41	After oscillation for 15' at + 20 lbs.
10.47	15.73	5.21	After oscillation for 5' at + 20 lbs.
6.07	16.19	5.36	After oscillation for 30' at + 20 lbs.

On gentle oscillation the gas is given off without bubbling. Bubbles only occurred when the water was roughly shaken. This shows how stage decompression is safe as far as regards the watery part of the blood. Oil, on the other hand, bubbles when left quite at rest. It is probable that the fat in the blood, liver, etc., starts the bubbling, and fat eaten increases the amount of this. Flatulence should be avoided. We lost six goats on one occasion—decompressed from + 90 to + 20, after a big meal of vegetables. They had chewed the cud at + 90 pounds, and died from gaseous distension of the stomach.

Conclusion.—The practical conclusion of the above review is that while decompression times at caisson works are often too short, those tabled by the Admiralty Committee are unnecessarily long. Particularly is this so if the men be persuaded to exercise their bodies during decompression. While the evidence of the superiority of the stage over uniform method is not so marked as the Admiralty Committee maintained, I find a stage method can be made fairly safe, and is the best one to use for caissons.

I think that a stage at + 8 pounds lasting 15 minutes is enough after a shift at + 30 pounds, and a stage of 30 minutes at + 15 pounds, after a shift at + 40 to 45 pounds, provided a medical lock for recompression is at hand. Five minutes in the first, and 10 minutes in the second case, should be given for completing the decompression. Von Schrötter recommends for + 1 to 1½ atmospheres a shift of 6 to 8 hours and decompression in 10 minutes, quicker at first; for + 2 atmospheres a shift of 6 to 8 hours decompression to + 0.8 atmospheres in 3 minutes, and then to + 0 at rate of 4 minutes per 0.1 atmosphere; for + 3 atmospheres a 3 to 4-hours shift and decompression to + 1.5 atmospheres in 3 minutes, and then to + 0 at rate of 4 minutes per 0.1 atmosphere. If the men can be arranged to climb from top to bottom of the shaft during the stage it will greatly increase their safety. The breathing of oxygen from a Fleuss apparatus for five minutes before decompression would act in the same way, and if this were combined with exercise at the stage, the time of decompression might be safely shortened. But how much, further experiment will show. Fat and the older heavy built men must be excluded, and all men with a defective circulation or pulmonary ventilation.

* I have invented a simple oxygen generator and inhaler, by means of which a bag of oxygen can be made by the action of water on oxylith (Na_2O_2). This could be used easily in a caisson.



A New Fourteen-Wheeled Express Locomotive

A Fine Example of Modern Engineering

By Charles R. King

The latest European development of the freight type of locomotive for express train services on mountain gradients is of novelty in having twelve connected wheels without resort to the Mallet system of articulated frames such as has hitherto been considered necessary for six pairs of driving wheels.

The new type of locomotive, built to the designs of Chief of Motive Power Karl Goelsdorf, Austrian State Railways, at the Florisdorf-Vienna Locomotive Works, overcomes the difficulties arising from the use of twelve connected wheels in a rigid frame by the introduction of universal coupling joints in the rear section of the side rods for connecting the fifth and sixth pairs of driving wheels, as shown in the accompanying photograph. This universal coupling for the side rods allows of the rear, or seventh, pair of wheels being arranged for a lateral play of 1 9/16 inches on either side. In addition to this, four other axles have lateral play so that the rigid wheel base of the engine is confined to the second and fourth pair of wheels. The arrangement is as follows:

Pony truck 2-inch displacement on both sides.
First connected wheels—rigid.
Second connected wheels—1-inch displacement on both sides.
Driving wheels—bald tires.
Fourth connected wheels—1-inch displacement on both sides.
Fifth connected wheels—rigid.
Sixth connected wheels—1 9/16 inches displacement on both sides.

The side rods are composed of five sections, each one allowing for the displacements of the wheel pin to which it is connected. The fifth section is a trussed rod, the remaining rods being of the usual I channel section. The whole arrangement of the wheels gives sufficient lateral flexibility to the locomotive without employing the Mallet articulated type, and with due regard to the lightness of the roads of the Austrian State Railways which do not allow a load of over 14 tons per axle.

For many years past a number of complicated systems of articulated connecting rods or ball axles—as the Engerth, Hagans, Klose, Klein-Lindner and others—have been used in Europe as alternatives to the Mallet system, but none present a simplicity equal to the present application whose success is probably due to the extended previous experience of the designer of the engine. His special methods for lateral play in axles have been very generally imitated by railways where locomotives have to be built for curves of short radius on trunk lines. In the light roads of Central and Eastern Europe the distribution of the engine weight over many wheels is obligatory and the adhesion weight of 43 metric tons employed for some Austrian six-connected express engines is becoming insufficient for rapid starting of heavy trains in all weathers. It is interesting, therefore, to remark that a modification of the Goelsdorf arrangement described would permit the use of eight connected wheels of about 78-inch diameter, and so would permit the total adhesion weight to be increased to about 56 tons with an axle load of only 14 tons. It appears probable that the use of eight connected wheels will eventually become necessary for express locomotives on light roadbeds in eastern Europe and in that case a flexible connection of the eight wheels will have to be introduced.

The new twelve-connected express engine is of the Central-European balanced compound type with all four cylinders in line, the larger pair, for the second expansion, being placed outside. The steam is of 227 pounds maximum pressure superheated to about 650 deg. F. After exhausting from the inside pair of cylinders, the superheated steam is passed to a pair of outside cylinders, having a capacity 2.85 times that of the horse-power cylinders. The second expansion serves to greatly increase the power of the engine for a given steam consumption and this permits the use of a smaller and lighter boiler than would serve for simple expansion, with a consequent economy in weight that is of material importance on mountain railways. The designer of this engine has ascertained by extended experience that it is only by making the low-presure cylinders nearly three times as large as the high-pressure and constructing the entire engine as simply as, or much simpler than, single-expansion locomotives, that 30 per cent to 35 per cent economy by compounding becomes possible.

The new balanced compound engine illustrated is intended for passenger trains of 400 to 450 tons and for grades of 25 per 1,000. In service it is found to maintain a speed on favorable parts of the line of 50 to 53 miles per hour with perfect steadiness of movement.

In the details there is a slight divergence from those customary in Austrian practice. It is worth noting how neatly the main rods are made to drive on the fourth axle in the engine, although the third axle comes in the way of the inside rods. Usually an undesirable complication, such as bifurcated main rods, bent axles, etc., are introduced to clear the obstruction. In this case it has sufficed to slightly incline the inside cylinders and shorten the inside rod to 6 feet 4⅞ inches as compared with the outside rod of 9 feet 6¼ inches length. The cylinders are 17¾ inches and 30 inches diameter and the piston stroke in all cases 26 13/16 inches. Driving wheels are 53½ inches in diameter and pony wheels 39¼ inches in diameter. The two valves, high pressure and low pressure, are both 18¾ inches in diameter and the throw of the valve-crank is 9 13/16 inches. The heating surface of the boiler is 3,185.5 square feet, of which 187.2 square feet is derived from the firebox and 505.8 square feet is due to the superheating pipes. The small flues are 2 3/32 inches outside diameter and the large mantle flues 5¼ inches and these latter considerably reduce the steam generating heat surfaces. The greatest weight on the axles is 13.85 metric tons, the least on the trailing connected axle, 13.35 tons. On the pony axle it is 13.6 tons. Total adhesion weight 82.17 tons. Total loaded weight of engine 95.77 tons. Weight of engine empty 88.26 metric tons.

It is not the heaviest locomotive of the freight type in Europe but is the most powerful one with highly-economical steam utilization—which is equivalent to the provision of a much larger boiler.

The Earth as a Radiator.—In a paper presented before the recent meeting of the British Association, Prof. W. J. Humphreys discussed the relation between climatic conditions and the radiation received and emitted by the earth. An abridged report of this paper, published in *Engineering*, is given below: Since climates were not at present growing perceptibly colder or warmer, Prof. Humphreys pointed out, the total amount of heat received by the earth during the course of a year must be substantially equal to the amount lost through radiation. But this did not hold for limited areas. The rate of gain was very variable, and ranged from zero to 2 calories per minute per square centimeter; the instantaneous maximum was on the southern tropic. The rate of loss was more regular than the gain, owing to the storage of heat in the soil, air, and water, and because of the latent heat of fusion and evaporation. A considerable amount of heat received in a warm district was entrapped and carried to colder portions of the earth, where it was radiated into space. The nature, height, and distribution of the clouds were important factors in these considerations. The low-lying clouds of high latitudes were below the radiating level, while the very high clouds of the tropics were above it; on account of the strong absorption of waves of great length by water vapor, the clouds allowed solar radiation to enter, but prevented loss of radiation from the earth. In the isothermal layer radiation alone was the controlling factor. The temperature of the isothermal layer was now known for many localities, and it was hence possible to compute the absolute intensities of the earth's radiation for different latitudes. Assuming that these intensities varied as the fourth powers of the temperature of the isothermal layer, Prof. Humphreys calculated the following table for the outgoing radiation in gramme calories per square centimeter per minute:

Latitude, degrees....	0-10	10-20	20-30	30-65	65-70	70-[illegible]
Intensity, degrees....	0.26	0.27	0.31	0.34	0.31	[illegible]

As a radiator the equatorial zone was least effective

A High Speed Cast Iron Flywheel*

A Neat and Orginal Design

By W. Trinks

Average practice in the design of cast-iron flywheels dictates an upper limit of a mile a minute or 88 feet per second for the mean rim speed. Since the hoop stress in a revolving cast-iron ring is given by

$$\frac{(\text{feet per second})^2}{10}$$

the hoop stress in average flywheel practice is less than 800 pounds per square inch. The tensile strength of cast iron is about 22,000 pounds per square inch and at first thought the factor of safety of

$$\frac{22{,}000}{800} = 27.5$$

seems ridiculous. Yet the occasional bursting of a flywheel preaches caution and deters engineers from adopting higher speeds. It is known that the difference between simple theory and actual practice is caused by four different agencies:

(1) The weakening of the rim by the joints of sectional wheels;

(2) Casting stresses;

(3) The bending of the rim by the forces in the arms;

(4) Flaws.

It is found even by approximate calculation that the weakening effect of the common form of joint is very great indeed. The author has never seen a complete theory of flywheel joints which considers the concentration of local stress due to the action of the fasteners (links, bolts or keys), the influence of the bending moment and the action of shrink links due to their initial tension beyond the elastic limit.

Casting stresses depend not only upon the design of the wheel but upon foundry practice as well; they are uncertain, and in many designs of wheels their presence cannot be detected. The author remembers a wheel of standard design which, while lying peacefully in the yard of a foundry, pulled an arm off, near the hub, even before the wheel had been delivered to the machine shop. To judge from this one example, even no speed is too high for a flywheel. Fortunately, such a sad combination between poor design and poor foundry practice occurs but seldom.

The bending of the rim can produce unexpectedly high stresses, particularly in shallow-rim pulleys. These can be mathematically determined, however, and thus kept within safe limits. An example will be given later.

Flaws furnish another valid reason for using a high factor of safety. They are similar to shrinkage stresses inasmuch as they escape discovery so long as the wheel is intact. They differ from shrinkage stresses because flaws are usually located by a post-mortem examination. Sudden changes of cross-section favor the formation of flaws and should therefore be avoided. A discussion of the manner in which to avoid flaws by correct foundry practice does not belong in this article.

In the summer of 1910, the author designed for the Mesta Machine Company, builder, and the Cambria Steel Company, purchaser, a flywheel with an outside-rim speed of 10,000 feet per minute.

The wheel is shown in Figs. 1 and 2. It will be seen that there are no rim joints. It was found that a 17-foot wheel could be shipped solid from the works of the builder to those of the user in spite of the distance, about sixty-five miles. The absence of rim joints, of course, eliminates the weakening effect of such joints.

The elimination of casting stresses was quite serious. It is well known that, in general, large solid-rim wheels are shunned by engineers, not only on account of the difficulties of transportation and erection but because great and uncertain shrinkage stresses are found in them. The illustrations show the various features which were employed to avoid these stresses. First, the arms, while made solid with the rim, were not connected at the hub; thus, they could shrink independently of each other. Second, the arms pass with long sweeping curves into the rim and into the hub section for the purpose of shoving the sand of the mold sideways by wedge action and thereby avoiding surfaces which could grip the sand and thus prevent free and unhindered shrinkage. This feature was made possible by splitting the wheel into two wheels, bolted together at the rim and connected to a common hub. Third, the dishing of the arms allows bulging out during the cooling of the casting, if resistance should be offered by the central core. It may be mentioned here that the foundry did its share in avoiding stresses, for instance, by making the cores between the arms soft and comparatively loose so that they could not offer undue resistance to shrinking.

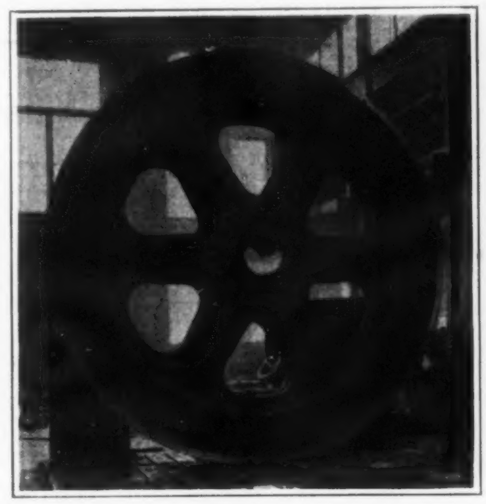


Fig. 1.—Flywheel Designed for a Rim Speed of 10,000 Feet per Minute.

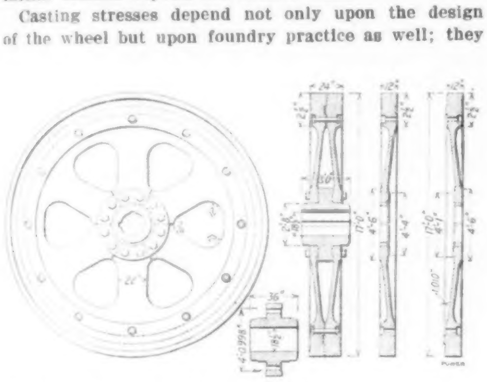


Fig. 2.—Showing Principal Dimensions of Flywheel.

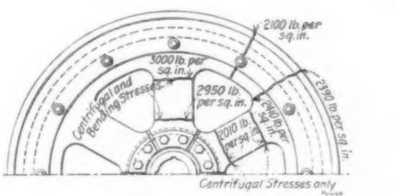


Fig. 3.—Diagram Showing Location of Stresses.

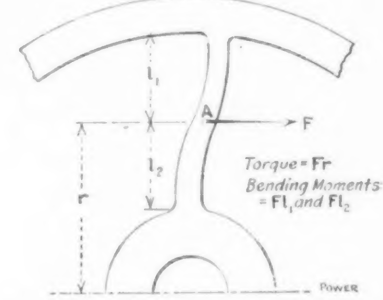


Fig. 4.—Illustrating Effect of Bending Stresses.

The fourth weakening effect, namely, flaws, may be mentioned in this connection. Splitting the wheel in two was done with the intention of avoiding unduly heavy sections. "Soundness to the core" is much harder to obtain in heavy sections than in light or medium sections, as explained in the various textbooks and periodicals on foundry practice. Besides, the gradual passage from the arm section to the rim section tends to prevent cavities in the casting, a point which is not to be despised.

With the shrinkage strains practically eliminated, the determination of centrifugal strains in the arms and in the rim can be made with some accuracy. Since a woeful amount of ignorance exists on the distribution of forces in flywheels a review of the method of calculation will probably be welcomed by "seekers for the truth."

Imagine the rim of a wheel rotating by itself—that is, disconnected from the arms; then its diameter will grow a small amount. Next imagine the arms rotating disconnected from the rim; then they will also grow in length, but not as much as did the rim. If both rotated separately, there would consequently be a gap between the arms and the rim. In reality there is no such gap, from which it must be concluded that the rim pulls the arms out and that the arms pull the rim in. From the size of the gap and the dimensions of the wheel the force acting between the rim and the arm can be computed in this manner. The arm is a rather stiff spring with a certain scale; the rim is a spring with another scale; the imaginary gap furnishes the deformation of both springs due to the force under consideration. These data together with the self-evident condition that the force on both springs must be alike (one being the reaction for the other) make the calculation determinate. A few words may be said about treating the arms and the rim as springs. The arms are straight bars and their deformation by direct tension is easily computed. The rim presents more difficulties as its deformation is made up of two components: First, a reduction of the diameter of the rim by the hoop tension which balances the arm pull; second, a flexure of the rim by the arm pull. All of these calculations, namely, the computation of the size of the gap, the stiffness of the two springs, the rim-to-arm pull and the resulting stresses, are thus purely a matter of applied mechanics; they offer no fundamental difficulties, but are very tedious, because no general formula can be employed.*

Undoubtedly an outer-rim speed of 10,000 feet per minute will be called recklessness by many, and for their special benefit the stresses found by the above outlined method will be given.

The principal stresses have been entered on the diagram in Fig. 3. The ideal hoop stress, as computed from the formula for a thin revolving ring, amounts to 2,150 pounds per square inch. On account of the depth of the rim the bending by the arm pull does not increase this stress materially. Thus the stress in the rim near the arm is 2,410 pounds per square inch, whereas the stress midway between the arms is only 2,100 pounds per square inch. The stresses in the arms due to centrifugal force are also small, amounting to 2,390 pounds per square inch near the rim and to 2,010 pounds per square inch near the hub. The material of the wheel (air-furnace iron) showed a tensile strength of 30,000 pounds per square inch. Since the design practically eliminates all casting stresses, this wheel should be very safe in spite of its speed.

Naturally, flywheels are intended to store up and give out energy, which process involves bending stresses in the arms. In the wheel under discussion the power to be transmitted was not specified by the purchaser because the varying temperature of steel in the rolls will vary the power required between extremely wide limits. Therefore, the builders reversed the method of procedure and computed the greatest power which can be transmitted by the wheel at a given speed with a given fiber stress in the arms. If the sum of centrifugal and bending stresses is limited to 3,000 pounds per square inch in the arms, as indicated in Fig. 3, the wheel can deliver or store up power at the rate of 21,000 horse-power. The builders felt satisfied that the rolls or roll housings would let go before the wheel if any such amount of power were required.

A few words should be said on the subject of bending stresses in the arms because much confusion exists in the minds of many engineers on this point. Each arm is rigidly held at the hub and is more or less rigidly held at the rim; it can therefore deflect only as is shown in Fig. 4, presenting an inflexion point *A* whose location depends upon the relative stiffness of the arm and the rim. In flywheels proper with deep rims the point *A* lies near the middle of the arm. In pulleys with shallow rims the point *A* lies near the outer end of the arm. The exact location of the inflexion point can be mathematically determined, but the process is tedious, and a skilled designer soon learns to guess the location of this

* Reprinted from *Power*.

* Stanwood and Lanza tried to derive such formulas (see *Transactions* of A. S. M. E. of the years, 1892 to 1895). J. Goebel gave a complete derivation in Z. D. V. D. I. (March, 1898), but his formulas, although correct, are too complicated for practical use.

point with considerable accuracy. Force *F*, Fig. 4, times the radius *r* gives the transmitted moment. This simple reasoning teaches that the bending at the rim is frequently just as great as the bending near the hub.

The outer rim speed of this wheel, as before mentioned, is 10,000 feet per minute, but this is by no means the commercially attainable limit. Wheels with plate walls gripping over a steel rim in halves can be run safely at 15,000 feet per minute. The simple formulæ for hoop stress then are no longer applicable, because solid disks have taken the place of arms. We all know that properly designed disks can be run at very high speeds, thus the De Laval disk, for instance, can be run with safety at a speed of 72,000 feet per minute.

While it is thus apparent that much higher rim speeds may be used than have heretofore been customary, it should not be overlooked that commercial rim speeds depend not only upon strength of materials and design but also very largely upon dollars and cents. Rotative speeds in steam-engine practice have been moderate, and low rotative speeds do not permit high rim speed without excessive diameters of wheels. An extreme case will illustrate the point: An engine which is direct-connected to a tin-plate mill and runs 30 revolutions per minute would have to be equipped with a 160-foot diameter wheel to attain the before mentioned rim speed of 15,000 feet per minute. Such a wheel would be all arms or all plate without any rim and would be preposterous. Electric motors and high-speed gas engines, on the other hand, can make use of high peripheral speeds. The proper rim speed for flywheels has, therefore, ceased to be solely a question of strength, but must be decided from case to case.

Suggestions for a Flying Machine*

A Historical Curiosity

By Emanuel Swedenborg

[*It is probably not very generally known that among the earliest suggestions toward the construction of a flying machine, is one from the remarkably versatile mind of Swedenborg. A translation of the original documents relating to this has recently been published by the Swedenborg Association, and is reproduced here in view of its quaint historic and personal interest.*—Ed.]

INTRODUCTION.

By Alfred Acton.

In the letter enumerating fourteen inventions, including "A flying vehicle or the possibility of being sustained in the air and being conveyed through it," Swedenborg says: "I am very glad that I have come to a place (Rostock) where I have time and leisure to gather up all my works and thoughts, which have hitherto been without any order and are scattered here and there upon scraps of paper. I have always been in want of a place and time to collect them. I have now commenced this labor, and shall soon get it done." And then, after listing fourteen inventions, he adds: "These are my mechanical inventions which have heretofore been scattered through various sheets of paper, but are now almost all reduced into order, so that they may be published whenever opportunity offers. In a short time, I will forward you the drawings at which I am now working daily."

The drawings were forwarded apparently as they were completed, for in a letter, dated Greifswalde, April 4th, 1715, shortly before his return to Sweden, Swedenborg writes: "By the last mail, I sent inclosed in my father's letter a drawing of an air pump to be worked by water. In my last letter to my father I promised to send you by every opportunity, and in each of his letters, some machine or other of my invention. I shall continue to do so for some time. . . . Further, it is my intention, of which I hope you will approve, to send over some of [the descriptions of] my machines for the examination of the Upsala people, and thus to prepare them for publication when an opportunity offers. This may perhaps be a little foundation for a society in Physics and Mechanics among us, like those in other places."

Whether or not the drawings and descriptions of all these inventions were thus sent is not known. But that some were sent is certain, for among Benzelius's papers, preserved in the Cathedral Library of Linkoping, we find, in Swedenborg's handwriting, "A discription of a machine for Flying; with a drawing." . . . Of this flying machine, two descriptions are extant, namely, the manuscript in the library of Linkoping, and the published account, taken from the *Daedalus Hyperboreus*.

The manuscript, which may be consulted in *Photolithographed MSS.*, vol. I, pp. 21-22, bears no date, but the nature of its contents indicates that it is one of those documents which were "reduced into order" from the "scraps of paper" on which Swedenborg jotted down his inventions as they occurred to him. The indication is made more clear by the fact that this manuscript was found among the papers of Eric Benzelius; for, as already noted, it was to Benzelius that Swedenborg wrote in 1714, that he was "reducing into order" his various mechanical inventions, and that he would "in a short time" forward the drawings, at which he was "working daily." We, therefore, fix the date of this manuscript as September, 1714, or soon afterward.

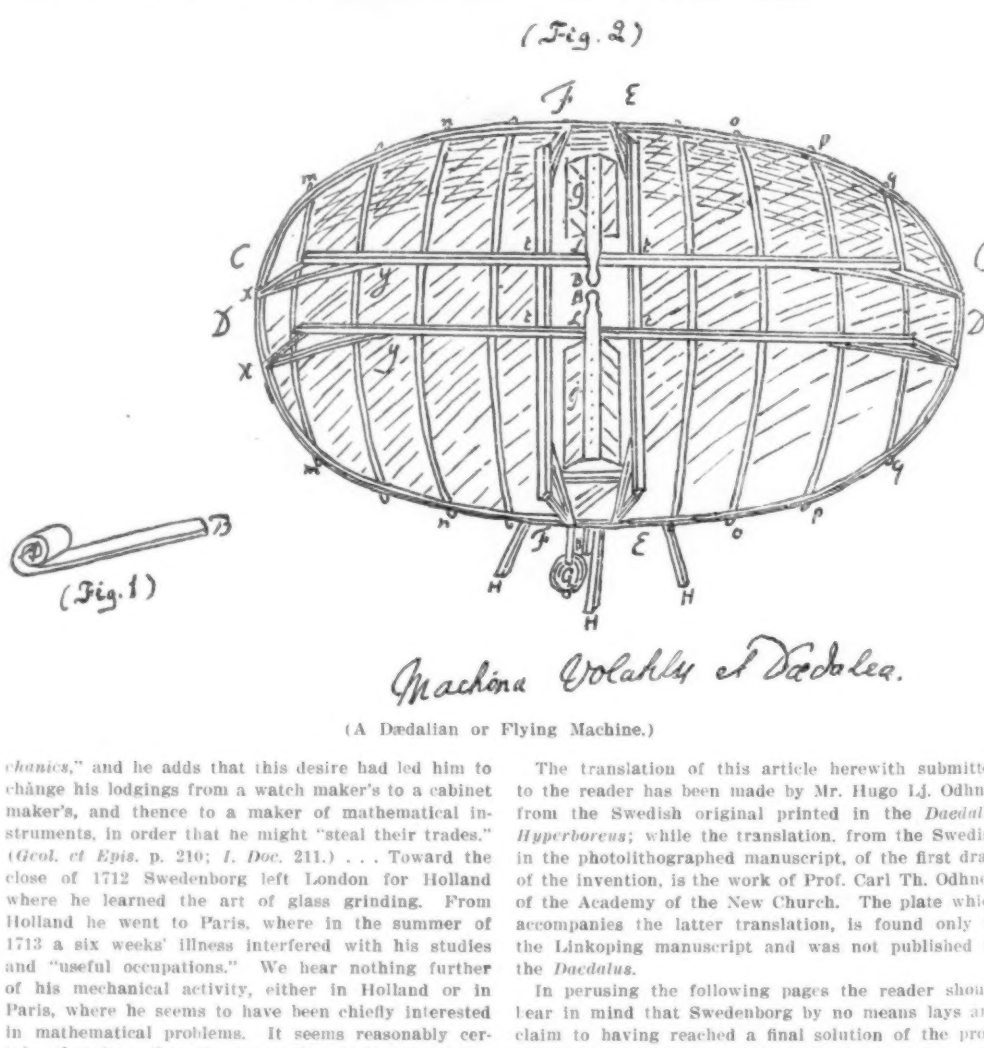
The "scraps" or "various sheets of paper," on which the manuscript was based, were in all probability destroyed by Swedenborg himself. The date of these sheets, if it could be ascertained, would, of course, fix the date of Swedenborg's first definite conception of a flying machine. Under the present evidence, however, nothing more specific can be said, than that the invention had its birth during the author's first foreign journey, from the fall of 1710 to the fall of 1714. Of this, however, there can be no doubt. For in 1714 Swedenborg writes to Benzelius, with whom he had been in close intercourse just previous to his leaving for London in the latter part of 1710, describing his flying machine as one of his "new" inventions.

During this first journey Swedenborg was much occupied with mechanical contrivances. Writing to Benzelius from London in April, 1711, he speaks of having an "immoderate desire for astronomy and mechanics," and he adds that this desire had led him to change his lodgings from a watch maker's to a cabinet maker's, and thence to a maker of mathematical instruments, in order that he might "steal their trades." (*Geol. et Epis.* p. 210; *I. Doc.* 211.) . . . Toward the close of 1712 Swedenborg left London for Holland where he learned the art of glass grinding. From Holland he went to Paris, where in the summer of 1713 a six weeks' illness interfered with his studies and "useful occupations." We hear nothing further of his mechanical activity, either in Holland or in Paris, where he seems to have been chiefly interested in mathematical problems. It seems reasonably certain, therefore, that the conception of the flying machine, first occurred to him in London or Holland, probably in the former place, in 1711 or 1712, thus while the author was about 23 or 24 years old.

Soon after his return to Sweden in 1715, Swedenborg's desire for a "Society in Physics and Mechanics," led to his publishing a journal, *Daedalus Hyperboreus* (*The Northern Inventor*) specifically devoted to these branches of science. Of this journal, six numbers of which were issued (1716-1718), Swedenborg was the editor, and he and Polheim were practically the sole contributors.

In the fourth number, published in 1717, we find the document, the present translation of which we have entitled "The Published Account." In the *Daedalus* it is described as "A project for a machine with wings and sails by which one may attempt to fly in the air; by N. N. with Assessor Polheim's objections." The N. N. is a pseudonym for Swedenborg.

The evidence points to the summer or fall of 1716 as the date of the writing of this published account. It was then submitted to Polheim, together with the other contents of the forthcoming fourth number of the *Daedalus*. For on September 5th, 1716, Polheim writes Swedenborg, "With great pleasure I read through the fourth number of your *Daedalus*, which, as far as I can see, is worked up with great industry and understanding." Then follow some reflections and criticisms on the article on the "Flying Machine," all of which Swedenborg added *verbatim et literatim* to the article itself when published.



(A Dædalian or Flying Machine.)

The translation of this article herewith submitted to the reader has been made by Mr. Hugo Lj. Odhner from the Swedish original printed in the *Daedalus Hyperboreus*; while the translation, from the Swedish in the photolithographed manuscript, of the first draft of the invention, is the work of Prof. Carl Th. Odhner, of the Academy of the New Church. The plate which accompanies the latter translation, is found only in the Linkoping manuscript and was not published in the *Daedalus*.

In perusing the following pages the reader should bear in mind that Swedenborg by no means lays any claim to having reached a final solution of the problem of aviation or even that his machine, so far as he had developed it, could be used with any success in actual flight. Indeed, the opposite is rather the case; for he somewhat grimly assures his reader that the experimenter with this machine, "might have to pay for the experience, and must not mind an arm or a leg." His articles, as is indicated in the title of the "Published Account," were intended only as being in the nature of "suggestions" for a flying machine. The youthful engineer was content to give a rough plan for the carrying out of his fundamental idea, well knowing that its perfection in details must necessarily be left to the experience of practical aviators. Therefore, speaking of the requirements which he lays down in some detail as essential to the construction of a practical flying machine, he says: "If these requisites are observed, perhaps, in time to come, some one may know how better to utilize our sketch and cause some additions to be made so as to accomplish that which we can only suggest."

His "invention" lies in the fact that, so far as is known, he was the first discoverer of the principle of

* Swedenborg Scientific Association, Philadelphia, Pa.

the aeroplane. At his time the balloon was universally held as offering the only possible solution of the problem of flight through the air. But Swedenborg, while still a youth of twenty-three or twenty-four, boldly rejected the principle of the balloon as being "contrary to our atmosphere"; and then, seeking his patterns in nature's aviators, the birds, and carrying his thought along new and original lines, he evolved the idea of flight by air planes, and also worked out, in general, the means by which such planes might be successfully constructed. In this he anticipated by more than a hundred and fifty years, the aeroplanes which so greatly excite the admiration and wonder of to-day—machines which fully prove the soundness of Swedenborg's idea, and demonstrate the fundamental correctness of the means which he suggests for carrying that idea into execution.

I.

THE MANUSCRIPT.

DESCRIPTION OF A DÆDALIAN OR FLYING MACHINE.

1. Make a square box or car, *t t t t*, of lightest possible material, such as leather, cork, or, best of all, birch bark, with thin wooden splints, the whole, however, strong enough to hold a man without danger. The box should be 2 ells (yards) in length and 3 in width, for the wings are to be moved sideways and the box, therefore, should be greater in width than in length; the depth should be 1 ell with space within for a Dædalus or aviator.

2. A sail should be stretched as wide as possible and be bent into a hollow; examine it carefully to make sure that there is no rift or crack in the sail for the air to pass through, for the pressure of the atmosphere will be so strong that if there be any rift, the air will be forced through with a whistling noise. The sail should be 150 square ells; for since an eagle or glead occupies about 2 square feet of surface when it lies still in the air, with tail, body, and all, therefore, as our flying machine with all its gear will be about 300 times heavier than an eagle, it must also occupy a space 300 times greater than an eagle in relation to its weight, that is to say, 150 cubic (square?) ells.

The sail may be made in the form of a square, oblong, circle, just as you please; best, perhaps, would be an oval form, provided with a support.

3. The sail is fastened and bent as may be seen from the drawing (Fig. 2), viz., there are four poles lengthwise and crosswise, *CC, DD, EE, FF*, all of which are bent at the ends, at *yx, yx*. Then make a thin wooden rim around it, *D C m n F*, bent into an oval shape. To this rim are fastened the splints, *m m, n n, o o*, which are also bent, and underneath all this the sail is securely fastened.

4. The two wings, *J J*, are placed between the sails, and they also should be bent into a hollow, in order to catch and keep the air better at the downward stroke than at the upward. It would do no harm if they were tilted obliquely backward, like the arms of a wind mill. They may be made of splints covered with sail-cloth, so fastened to the spints above that it opens a little at the upward stroke, for the air to press through.

5. *L L* is the true center of the machine, where it lies in a balance. The wings must also be balanced, so that *B B* on the one side is equal in weight with *J J* on the other. The wings should be as light as possible, but the most important thing in connection with them is a spiral spring (*sling fjader*), placed lengthwise beneath each, shaped as in Fig. 1.

This spring is fastened to the car in such a manner that *A B* runs lengthwise along the wing, while *A* is fastened to the car itself. Now when the wing moves upward, *A B* moves against the spiral in the spring, so that the spiral circle in *A* is rolled up, but at the downward stroke it recoils and carries the wing downward with force.

6. *H H H H* are four poles proceeding downward, i. e., four legs; it would do no harm if they were provided with rollers, for the machine to stand upon.

G is a weight or beam (*vectis*), which is to keep the machine in a horizontal position, so that it may not tip over.

Requisites for the building of the machine. (1) The position of the poles and the splints may be seen from the drawing. (2) The seat is within the basket, and beneath there ought to be a bar under which the weight should be fastened. (3) The center of gravity or the balance, should be determined in the middle of the car—the machine should be placed between two poles and hung on two axles, from which it may be seen where the wings and the weight are to be fastened.

Requisites as to the weight. The weight of the whole machine ought not to be more than 20 Lispund,* or 1 Skeppund, viz., the man or Dædalus, 8 Lispund; the sails 150 or 160 square ells—2½ Pp.; the car itself 1½ Lp.; the framework, 5 Lp.; the weight, *G*, 1 Lp.; the wings, with the springs, 2 Lp.; the rest, 1 Lp. Altogether, 21 Lispund.

Requisites as to the size. The sails may be expanded in whatever form you please, to the size of 150 or 160 square ells. If the form is circular, then a diameter of 14 ells would be sufficient; if oval, then the larger diameter might be 16 ells, and the shorter 12; if square, then the side would be 12½ ells. If oblong, the longer sides ought to be 15, the diagonal 10 ells; all these dimensions would occupy a space of 150 or 160 square ells. (2) The car should be 2 ells long, 3 broad, and 1 deep. (3) The wings 2½ ells long, and three-fourths ell broad. (4) The weight or beam should be almost 4 ells from the bottom, when it would be able to keep in balance several Skeppund.

Observata. The springs below the wings ought to be strong and should weigh about 5 or 6 Lispund. (2) Where the sails are fastened (?) they ought to be bent inward. (3) The Dædalus himself should determine the flight by his swaying downward, upward, or to the side. (4) One must see if any (additional) sail be necessary to direct the course, downward or perpendicularly.

PROOFS.

1. From eagles or gleads, which are able to lie still on their wings or on their expanse, or sway in the air.

2. From paper-kites, which often in calm weather are able to keep themselves in the air, and rise higher and higher up by only a slight motion, and yet not tip over, although surrounded by wood and other heavy materials.

3. That Kirchberg, and others, tell about such things although nothing (———) is seen expanded.

4. That the wind can lift up very heavy materials, so that when it blows against a gate with force, it can blow it open even though two men be pushing against it, when yet it is often 16 square ells in extent. How, then, would it act on a surface of 150 square ells, with the wings helping along?

5. A student with a side-cape fell unharmed down from Skara Church tower in a strong wind.

6. A kite, the higher it reaches, the less motion is needed to keep it in the air, as is apparent; while down by the ground it has to be lifted up by motion.

OBSERVATA.

A machine such as this can be made to go when there is a strong wind; otherwise it will remain still. roof, after it has been weighted with ballast, to the

It may be drawn forward on the rollers, where the ground is even. Or it may be pushed down from a weight of a man.

II.

THE PUBLISHED ACCOUNT.

SUGGESTIONS FOR A MACHINE TO FLY IN THE AIR.

From the thought of Assessor Polheim (in a preceding article on "Rational Duplicates in Perpendicular Falls") we may figure out the power and resistance of the air to all objects, expanded as well as compact or compressed. From this, as also from the flight of birds, it would be easy to come to the conclusion that a machine might be invented which could carry and transmit us through the air, and that we are not to be excluded from the element overhead, even though no other wings be given us than those of the understanding. Those who before now have given thought to such a work of Dædalus or Mercury, have set before them an impracticable principle, and have founded their notions on things contrary to our atmosphere, viz., great balls which, by being emptied of air, acquire a sufficient lightness to raise up a machine and its Icarus as well.

But if we follow living nature, examining the proportions that the wing of a bird holds to its body, a similar mechanism might be invented, which would give us hope to be able to follow the bird in the air. First, let a car or boat or some like object be made of light material such as cork or birch bark, with a room within for the operator. Second, in front as well as behind, or all around, set a widely stretched sail parallel to the machine, forming within a hollow or bend, which could be reefed like the sails of a ship. Third, place wings on the sides, to be worked up and down by a spiral spring, these wings also to be hollow below in order to increase the force and velocity, take in the air and make the resistance as great as may be required. These, too, should be made of light material and of sufficient size; they should be in the shape of bird's-wings, or the arms of a windmill or some such shape, and be tilted obliquely upward and be made so as to collapse on the upward stroke and expand on the downward. Fourth, place a balance or beam (*vectis*) below, hanging down perpendicularly to some distance and with a small weight attached to the end, pendent exactly in line with the center of gravity—the longer this beam is, the lighter it must be, for it must have the same proportion as the well known (Roman) *vectis* or steelyard. This would serve to restore the balance of the machine whenever it should lean over to any of the four sides. Fifth, the wings would perhaps have greater force, so as to increase the resistance and make the flight easier, if a hood or shield were placed above them, as is the case with certain insects. Sixth, when now the sails are expanded so as to occupy a great surface and much air, with a balance keeping them horizontal, only a small force would be needed to move the machine back and forth in a circle, and up and down. And after it has gained (sufficient) momentum to move slowly upward, a slight movement and an even bearing would keep it balanced in the air and would determine its direction at will.

It seems easier, however, to talk of such a machine than to put it into actuality and get it up into the air, for it requires greater force and less weight than exists in the human body. However, there are three or four requisites that would be of chief assistance: (1) a strong wind, which has a considerable effect on similar objects, for in calm weather it would be better to keep quietly and humbly by the ground; (2) the machine should be pushed off from a considerable elevation, for the primary difficulty will be to force oneself up from the level; much would be gained toward this end if the machine were lifted up some distance into the air by means of ropes; this would do as much as a strong puff of wind; (3) the size and width of the sails (as well as the force of the wings) ought to be in proportion to the weight, and must increase with the weight in the ratio of 3 to 2, as Assessor Polheim shows in the article below; (4) in order to acquire a downward force in the wings sufficient for moderately calm weather, the science of mechanics might perhaps suggest a means, viz., a strong and stiff spiral spring, which, when set free, would have the power of three or four persons; and it could be bent upward, though somewhat more slowly, by a light and quick mechanism.

If these advantages and requisites are observed, perhaps in time to come some one might know how better to utililze our sketch and cause some addition to be made, so as to accomplish that which we can only suggest. Yet there are sufficient proofs and examples from Nature that such flight can take place without danger; such as birds, eagles and gleads, which, as it were, swim in the air and with all their weight rest on their wings without moving the least feather for several minutes. In the case of kites, made of paper and wood, we see a similar property, in that they keep themselves up in the air without sinking down in the least. It is also well known that a man in Strangnas accidentally fell down from a tower in a strong wind, but the cape which he wore so far saved him, that he came to the ground unharmed. And there are other cases which may be considered; although when the first trials are to be made, you may have to pay for the experience and must not mind an arm or a leg.

The ingenious Fontenelle writes humorously about such a machine, saying: "The art of flying is as yet hardly born. It will be perfected and some day people will fly up to the moon. Do we pretend to have discovered everything, or to have brought our knowledge to a point where nothing can be added to it? Oh, for mercy's sake, let us agree that there is still something to do for the ages to come!" (*Entret sur la Pluralite des Mondes*, pp. 51, 52.)

The learned Assessor Polheim pronounces a more doubtful opinion, as follows: "As to articial flying it probably has the same difficulties as the artificial production of gold or perpetual motion, etc., although at first sight it seems no less practicable than desirable; but when we examine the matter more closely we meet something which Nature seems to deny us; as in the present case that all machines do not retain equal proportions in great dimensions as in small, even though all the parts be made the same and in the same proportion; for instance, although a cane or stick may be capable of carrying not only itself but also some weight in addition, yet this does not apply to all dimensions, even if the length and thickness keep the same proportions, for when the weight increases in triplicate ratio, the force increases only in duplicate; it is the same as to surfaces. Whence it happens that great bodies cannot support their own weight. And since Nature itself demands of birds not only a very light and strong material for feathers, but also wholly different tendons and bones in the body itself, which tend to strength and lightness, and which do not exist in other bodies; therefore, on account of the lack of necessary materials, it is much more difficult to accomplish that effect in the air which is needed for the realization of this thing, in case a human body is to accompany the machine. But if it were possible for one person to move and direct all that pertains to a machine sufficiently large to be able to carry him, then the point would be gained. However, it would be well to take advantage of a wind, if the same were constant and invariable."

But enough this time, about our Dædalus.

* The old Swedish "Lispund" = 18 lb. 12 oz. The "Skeppund" = 374 lb., or 171 kilogr.

System of Computing Interest.

By Robert Grimshaw.

Referring to the so-called Billings method of computing interest: I think my way of using most of the factors or constants is somewhat shorter. I assume that the operator can do short division and multiplication mentally. Here are my figures, and those of the Billings method, for comparison:

TWO PER CENT.

Billings.	*Grimshaw.*
84,716.11	Divide by 2 and by 9.
84,716.11	
84,716.11	4235
84,716.11	
84,716.11	Interest $4.70.
8,471.61	
8,471.61	Four figures before-result.
8,471.61	
8,471.61	
8,471.61	
847.16	
847.16	
847.16	
847.16	
847.16	
470,174.40	
Interest $4.70.	
98 figures before result.	

THREE PER CENT.

Billings.	*Grimshaw.*
84,716.11	Divide by 6 and by 2.
84,716.11	
84,716.11	1412
84,716.11	
84,716.11	Interest $7.06.
84,716.11	
84,716.11	Or divide by 4 and by 3.
84,716.11	
8,471.61	2118
8,471.61	
8,471.61	Interest $7.06.
847.16	
847.16	
847.16	
705,685.19	
Interest $7.06.	In each case four figures before result.
98 figures before result.	

FOUR PER CENT.

Billings.	*Grimshaw.*
84,716.11	Divide by 9.
8,471.61	
847.16	Interest $9.41.
84.71	
94,119.59	Result without previous figuring.
Interest $9.41.	
29 figures before result.	

SIX PER CENT.

Billings.	*Grimshaw.*
84,716.11	Divide by 6.
8,471.61	
8,471.61	Interest $14.12.
8,471.61	
8,471.61	Result without previous figuring.
8,471.61	
8,471.61	
847.16	
847.16	
847.16	
847.16	
847.16	
847.16	
84.71	
84.71	
84.71	
84.71	
84.71	
84.71	
141,136.99	
Interest $14.17.	
105 figures before result.	

EIGHT PER CENT.

Billings.	*Grimshaw.*
84,716.11	Divide by 9, multiply by 2.
84,716.11	
8,471.61	94
8,471.61	
847.16	Interest $18.82.
847.16	
84.71	Three figures before result.
84.71	
188,239.18	
Interest $18.82.	
54 figures before result.	

Trade Notes and Formulæ

Pocket Varnish.—Rosin, 200 parts; fir rosin, 100 parts; turpentine, 50 parts; chalk, 75 parts; oil of turpentine, 3 parts. For brown add to this mixture 100 parts of umber or bole.—*N. Erf. u. Erf.*

Easily Made Heat Insulating Mass.—Prepare a starch paste from 4 parts of starch and 100 parts of water, add saw dust to it until a suitably stiff, dough-like mass is obtained, with which the steam pipes may be coated. After drying the coating may be painted in any color.

Varnish for Rubber Shoes.—Hard rosin, 5 parts; shoemakers' wax (black), 15 parts; Syrian asphalt, 25 parts; coal tar, 5 parts; benzol, 50 parts; benzine, 10 parts. The rosin, the cobblers' wax, the tar and asphalt, are placed in a tumbling barrel, the benzol poured over them and the barrel kept in motion until the whole is dissolved. Then thin the varnish with the allotted quantity of benzine. As the varnish is difficult to filter, the greatest possible purity of the ingredients must be insured or the varnish must be allowed to settle very thoroughly.

Caterpillar Glue.—Rosin axle grease is quoted as the best medium for keeping the caterpillars from trees. A ring of paper is fastened to the tree with cord or wire and the wagon grease smeared on the paper. If the grease should be too thick, a little oleic acid may be added to it. (1) Mix 50 parts of blue rosin oil, 50 parts thick rosin oil (stock oil), and 0.5 parts of Para rubber solution and saponify with 5.6 parts of caustic lime paste. (2) 100 parts rosin, 70 parts lard and 66 parts rape seed oil. (3) 1,000 parts thick turpentine, and 500 parts of rosin are melted with 750 parts of pine tar.—*Or. f. d. Oel und Fetthdl.*

Packing Grease for Asbestos Disks.—To prevent asbestos disks from burning fast, they are smeared with a mixture of graphite and grease. The latter is mainly for the purpose of causing the graphite to adhere. For this reason quite a cheap oil may be used. The quality of the graphite is, however, of importance, flake graphite is the best, for a cheaper product washed graphite may be used and the graphite may also be in part replaced by talcum. A good recipe for such a product, is the following: Flake graphite, 50 parts; "Cosmos" cylinder oil, 20 parts; ceresine, 6 parts; spindle oil 0.885, 24 parts, by weight. Melt the oils and ceresine together and stir in the graphite. Stir until cold and transfer into cans by means of a spatula.

Insoluble Soap in the Treatment of Fibers and Textiles.—The soaps insoluble in water have hitherto been used in the textile industry only for making goods waterproof. E. Agostini would apply them also for sizing threads and finishing fabrics, without making these impermeable to water. The process mainly consists in introducing into the sizing or finishing mass the uncombined constituents of an insoluble soap, used simultaneously with a neutral fat substance (as a rule a fat vegetable oil) or a heavy carbohydrate (a mineral oil not volatile below 150 deg. C.). In drying, and only at this moment, the constituents of the insoluble soap unite, in consequence of the increase in temperature; the resultant soap enters into a combination with the fat or the mineral oil and there is produced a fatty substance which firmly holds the remaining sizing or finishing substance. In consequence of the formation of the insoluble soap in the fibers, the substances are not merely deposited on the surface but penetrate into the interior of the thread and are permanently retained there, resisting even washing. The process can be applied to printed and dyed goods, as well as to natural or bleached goods. The color shadings are well preserved and their fastness is increased by the process.—*Chemiker-Zeitung.*

Colored Marking Pencils.—These products consist of mixtures of different waxes that are melted down with body colors. Aniline colors are not suited for this purpose as pencils made with them do not make a distinct mark. According to the following recipe, a good result is obtained: 40 parts by weight of ceresine, 35 parts by weight of bleached carnauba wax, 20 parts by weight of paraffin, 5 parts by weight of bleached beeswax, 50 parts by weight of Venice talcum. As color we use for blue, 12.5 parts by weight of dark chrome green; yellow, 15 parts by weight of chrome yellow; red, 15 parts by weight of artificial vermillion; white, 10 parts by weight of oxide of zinc; black, 10 parts by weight of lamp black. For the dark-colored pencils, the waxes can of course be used in their yellow color. The making of these pencils is effected by melting the waxes and then adding the talcum and the respective colors. Heat for a time, stirring constantly, so that the color is distributed as evenly as possible and then pour the mass into glass tubes, corked at the bottom. The mass must be cooled to a thick fluid consistency before pouring out, so that the body colors do not settle. After cooling, the pieces are pushed out, trimmed top and bottom and wrapped in tinfoil paper.—*Der Chemisch-Technische Fabrikant.*

Science Notes

The Cause of the Deviation of Deep Bore Holes In most of the bore holes extending to a depth approaching a thousand feet, a marked deviation has been observed, which usually is directed northward. An explanation of this remarkable phenomenon is suggested by J. S. Curtis in the *Mining World*. In consequence of its rotation in the earth's magnetic field, the shaft and boring tool becomes strongly magnetized with the south pole pointing upward. The shaft being very long, the poles are not at the extremities, but some distance from the same. The attraction exerted by the earth's field upon the north pole of the shaft, situated at the bottom, produces a curvature of the shaft in such direction that its convexity is directed toward the south, and thus the boring tool receives an inclination causing the bore hole to deviate toward the north. This deviation accumulates more and more. In such cases, as the deviation takes places in some other direction than the usual one, the fact is probably attributable to the obliquity of the strata.

Limits of the Sense of Taste.—Some interesting observations are recorded by Dr. Glotzbach who has determined that cane sugar still imparts a distinct taste to water in a concentration of 0.12 per cent, while a solution of half this strength represents about the limit at which the mouth is still capable of detecting a sweet taste. The same figures as for cane sugar were obtained for sodium, potassium, and calcium nitrate, and also for sodium nitrite and magnesium and sodium sulphate. Common salt could be detected down to a concentration of 0.015 per cent. Still smaller figures were obtained for calcium sulphate, ferric chloride, ferrous sulphate, and cupric sulphate, the last named being observable even by a concentration of 0.0007 per cent. The substances of which the smallest quantities are perceptible are sulphuric acid and hydrogen sulphide, which can still be tasted in a concentration of 0.000115 per cent. The observer does not mention saccharine. It would be interesting to know what figure would be obtained in this case.—*Prometheus.*

The Leaf Fall of Trees.—The autumnal leaf fall of trees and shrubs varies within very wide limits in the different species. Thus, for instance, in the case of the Japanese gingko, the leaves are all shed within a few days, while beeches and oaks take many weeks to lose their leaves, and in fact retain some of them over winter. Some very interesting data have been collected by Prof. G. Kraus with regard to the leaf fall of a horse chestnut tree and a maple in the botanical garden at Halle, Germany. On October 26th, 1892, both trees were practically in full leaf. On the ensuing night there was a frost of —3.1 deg. C., and when on the next morning the sun rose at 8 o'clock, the leaves began to fall like rain. From the horse chestnut the leaves continued to fall for one hour, chiefly on the sunny side, after which they suddenly ceased. In the case of the maple, the leaf fall lasted only half an hour, and then stopped as suddenly as that of the horse chestnut. In that half hour 61 pounds of leaves fell, while the horse chestnut lost in one hour 135 pounds. From the determination of the average weight of one leaf, it was found that the maple had lost in all 16,518 leaves, or 9.2 per second, the horse chestnut suffered a total loss of 87,603, or 24.3 individual leaflets or over three entire leaves per second. The total leaf loss of the horse chestnut from October 27th until November 10th, when the last leaf fell, amounted to 276,900 leaves, weighing 445 pounds.—*Prometheus.*

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